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Technology Transfer: Investment in East Asia

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An Approach To Measure and Analyze International Technology Transfer: A Case Study on Japanese Firms' Direct Investment in East Asian Countries

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[Text]

1. Introduction

1.1 Background and Objective of Survey and Research

1.1.1 Background

Because the effect that science and technology has on society and the economy has increased, it is now believed that the solution to the economic gap between North and South must be approached from the aspect of science and technology. Inasmuch as Japan's international responsibilities are being loudly talked about these days, it is all the more desirable that Japan commit itself more actively to expanding science and technology cooperation to the developing countries.

Now, industrialization in the East Asian countries, to include the Asian NIES and ASEAN countries, has advanced remarkably, and Japanese firms' investment in these countries has played a certain role in their industrialization. The major portions of the East Asian requirements for capital and technology, it seems, were borne by Japanese firms. Therefore, when considering the problem of promoting technology transfer to the developing countries from an overall viewpoint, it is necessary to fully take into account activities of the private sector. In order to explore what role Japan will be able to play in helping the progress of technology in countries in the South, this case study describes in detail technology transfers from Japan to East Asian countries that have been induced by Japanese firms' investments in these countries.

Japan and East Asian countries are firmly bound not only economically but also technologically. In order to advance their own technology, many of these countries have been showing strong interest in Japanese science and technology and have been calling for technology transfer from Japan. However, there exists a wide gap in how one looks at technology transfer between Japan and those countries. In Japan, the increasing direct investment by Japanese private firms in East Asian countries is regarded as having contributed to the growth of those countries. That is, the conception in Japan is that building plants in East Asian countries and hiring and training local people contribute to the growth of industry in the host country. On the other hand, a strong voice is heard in East Asian countries that the Japanese firms have been niggardly in technology transfer and that more sophisticated kinds of operations and work should be shifted to the local operations in order to advance the technical levels of the host country. Technology transfer is becoming a political issue between Japan and East Asia, but the starting point of the problem—an understanding of the current state of technology transfer—is not yet clearly delineated. One reason for this is that the term "technology transfer" is an abstract idea and is hard to understand. Therefore, the current state of affairs needs to be clearly grasped before discussing technology transfer.

Analyzing this point will also help to clarify the features of technological progress in East Asian countries. The East Asian countries have rapidly been expanding their assembly industry in fields where the merits of scale can be taken advantage of, such as the production of watches and home electronics. Industrial growth in East Asian countries, however, has largely relied on the division of labor with Japanese and U.S. firms, and consequently they are relying on both countries for supplies of many of the required parts and components. Some East Asian countries have recently emphatically committed to the development of their own technology but the result has yet to bear fruit. Therefore, technical development has until now relied on technology introduced from the advanced countries. In order to understand the growth of technology in East Asia, it is necessary to understand the process of technology transfer from the advanced countries, especially Japan, while linking it with the international division of labor.

For other developing countries suffering from sluggish domestic economies, the success stories of the East Asian countries will help them in drafting the courses for industrialization of their own countries.

1.1.2 Objectives

Since technology transfer takes various forms and modes, it is necessary to narrow down the scope of targets and objectives of study. Although details are spelled out in Paragraph 2, this case study describes direct investment abroad, a subject having the greatest impact of all private business activities. By region, the economically as well as technologically advancing East Asian countries that have especially strong ties with Japan (four countries or regions referred to as Asian NIES, and Thailand and Malaysia; when not mentioned otherwise, hereafter "East Asia" means these six countries) (Note: Detailed data is provided in Item 3 of Paragraph 3.4) are described.

The objectives of this case study are the following: (1) to measure the current state of technology transfer accompanying the shift of production to overseas countries, by using a measuring method of technology transfer best suited to the advancing "borderless" in corporate activity; (2) to analyze the cause and effect of technological advance on technology transfer in this age when the competition for technological innovation is being

fiercely waged; and (3) based on the above data, to analyze the structure of technology transfer between Japan and East Asia.

1.2 Outlines of Existing Studies on International Technology Transfer Between North and South

For the reasons that it is difficult to define what technology is because technology is not a material and that technology transfer follows various courses, no single clear-cut framework for analyzing the subject has yet been developed. In the following are given reviews, although fragmentary, of discussions that have been held on technology transfer between advanced and developing countries, and consideration of what problems are there and what should be done to solve them in connection with technology transfer that follows accompanying Japanese direct investment in East Asia.

1.2.1 Product Cycle Theory

According to the famed "Product Cycle" theory by Vernon that theoretically explains the process of transfer of manufacturing technology overseas, technological innovation occurs in rich countries (higher wage countries) and the production technology, as it advances in maturity, filters down to lower wage countries. In reality, however, the expanding worldwide activity by multinationals that has taken place in recent years is following a different course than that espoused in the Product Cycle theory—the optimal place for production shifts from advanced countries to medium-level advanced countries to developing countries. For example, a Japanese firm has started producing a new VTR model about two years after its development in its local plants in Asian countries. The speed with which new technology spreads throughout the world is greatly increasing. Cases are increasing in which the optimal production site is determined based on corporate strategy rather than the technological as well as wage standards in the host country. In other words, the progress of borderless economy has forced the corporations to go beyond the product cycle theory into forming a sort of "simultaneous worldwide production system." A theory explaining the relationship between overseas investment and technology transfer that takes into account the reality described above is awaited.

1.2.2 Optimal Technology Theory

Second, there is the optimal technology theory (also called the intermediate technology theory), which, on the basis of the idea that developing countries will face various problems during the course of absorbing technology, discusses the issue of priorities in the introduction of technology when such countries prepare plans for technological introduction. This theory was raised in the wake of a series of failures of the plants that developing countries introduced from abroad in the 1960's and 1970's. The theory postulates that in view of various problems the less-developed recipients of sophisticated technology will face, technology transfer from developing countries to developing countries should start from the level of technology that the developing country will be able to use rather than from sophisticated technology. As the reason for this, the theory states that once the foreign engineers have gone home after the technology is introduced, it will be impossible for the recipient country to fix problems on its own and that there are not enough engineers in the recipient country to promote diffusion of the introduced technology. The theory further states that building the social infrastructure in developing countries demands the existence of employment and education systems closely oriented to the locality and that to that end, introduction of optimal technology is most desirable since it will lessen the burdens on the local community. In such a context, it is believed that optimal technology or intermediate technology is most suited to developing countries. This thinking is appropriate to modernization of domestic industry through the exploitation of resources and traditional skills.

However, in the industrialization of East Asian countries, because of their limited domestic market, the promotion of exports has proven to be a potent weapon. To promote exports, it is necessary to manufacture products which are competitive internationally. The electronics industry has grown rapidly in South Korea and Taiwan, and these countries at least must have imported not the optimal technology but the top-of-the-line technology. The technology may not have been the most sophisticated, but these two countries must have used high technology if only to make their products competitive on the world market. The Pohang iron mill in South Korea was then equipped with large-capacity blast furnaces, making their steel least expensive in the world. From the foregoing, technological advances in East Asia seem to suggest that there are different courses other than the optimal technology theory for growth for developing countries.

1.2.3 Construction of Econometric Models

Third, studies are being done to incorporate technology into econometric models as their constituent elements. For example, attempts are being made to form an equilibrium model with production as a function by assuming the existence of two commodity markets between two countries, and to incorporate technology into world economic models with technology as a function. Attempts are also being made to analyze the flow of capital between advanced countries and developing countries, trade between them, and economic welfare in each of these countries by incorporating in these models technology as a variable.

Attempts are also being made in the field of economic growth theories to incorporate technology as one constituent element. However, because technology can hardly be taken as a quantity, the occurrence of technological innovation cannot be anticipated, and an advance in technology has a dynamic side to it in that technological

progress impacts not only the environment but also the way the technology itself should be, efforts to establish decisive economic models seem to encounter tough going.

1.2.4 Technology's Tendency To Move as Information and Technology Propagation Theory

Fourth, attempts have been made to grasp more intrinsic characteristics of international technology transfer and have the findings reflected in the effort to form a framework.

One of these attempts is the discussion on how easily technology can jump corporate bounds when it is transferred to someone else. Some say that since production technology is a special kind of information specific to its corporate owner, taking the technology outside of the corporate framework and make it work is basically difficult. For international technology transfer to become feasible, the essential condition is said to be that the recipient has the technical potential to understand the special information and digest it. However, others point out that technology differs from materials in that it can be easily duplicated, owned jointly and copied.

Regarding the results of surveys that we conducted of Japanese firms who have experience in investing overseas, the majority said that "when developing countries introduce technology, it is difficult for them to completely understand the technological information because they have no experience in repeating the trial and error involved in the technology's development and hence lack the know-how born therefrom."

This suggests that despite the rapid advances in technological levels in East Asia, technology transfer from advanced countries to the area may not be so simple and easy. Overseas direct investment was once regarded with caution by developing countries because it would lead to economic control by the advanced countries over the countries receiving investment. However, when the difficulty that developing countries will encounter in trying to introduce technology is taken into account, the direct investment in which companies transfer technology to their overseas subsidiaries may be interpreted affirmatively as a method that facilitates technology transfer regardless of the technological levels in the developing country. Many of the East Asian countries have abandoned the wariness with which they once regarded foreign capital, and from the latter half of the 1970's to the 1980's, have switched policy to one seeking foreign capital aggressively.

There is a framework in which international technology transfer is regarded as a diffusion of technology. In this school of thought, the framework for sociologically analyzing the process of diffusion of substance in society is adopted to analyze the diffusion of technological innovations in society. This framework has yet to clearly analyze the process of technology transfer in the real world.

1.2.5 Functional Dispersion in Overseas Production Bases

Fifth, there is a study on the approach to technology transfer from the localization of firms advancing overseas. In this study, it was assumed that the parent-to-subsidiary technology transfer of the Japanese firms that have directly invested abroad began with assembly and proceeded to processing, design and development. These companies were surveyed through questionnaires. It reveals trends in how those Japanese companies have been shifting their production functions to their overseas subsidiaries.

Accompanying the start of production overseas, technology transfer is generally considered to take the following steps.

First stage: (1) assembly only, (2) manufacturing and processing, (3) maintenance of machinery and equipment, (4) quality control, (5) production control system, (6) knowing when to purchase or have parts, etc. ready

Second stage: (7) technology improvement, (8) personnel training

Third stage: (9) design technology, (10) product design, (11) die making

Fourth stage: (12) product development

1.2.6 Positive Approach

Sixth, many case studies have been conducted on technology transfer by the Institute of Developing Economies and others. These studies are mainly trying to clarify the actual state of technology transfer. Their contents cover a broad range of subjects pertaining to corporate direct investment including communication with the local host country, methods of providing guidance and education, contents of technology transfer, dispatch of Japanese workers to the host country, management of the local venture, and labor management measures, as well as the technology promotion policy, the foreign capital policy and the technological levels of the host country. Among the research themes relevant to our current case study is an analysis in which technology is classified into two categories, those technologies heavily dependent on R&D capability and other technologies, to analyze technology transfers accompanying investment by Japanese abroad (see the "Industrialization in Asia and Technology Transfer" by the Institute of Developing Economies).

As to why case studies have come to be vigorously conducted, the above book briefly describes as follows: "The difficulty of technology always comes to the fore even when considering technology transfer. It is difficult to specify what makes up technology, and technology transfer takes various forms depending on the technology's contents. It is advisable to probe where lies the problem after explaining the actual state in which industrial technologies have been transferred in the course of industrialization. In the case of technology transfer,

doctrinaire ideas or generalizations are more of a hindrance to problem-solving than a solution, so for now, the issue must be approached from a multifarious and substantive standpoint."

2. Perception of Importance of Technology Transfer, and Survey and Research Methods Used

Despite the efforts mentioned above, the people's perception of technology transfer has not yet fully deepened. From what angle should technology transfer between private enterprises in Japan and East Asia be analyzed?

2.1 Relationships Between Private Firms' Direct Investment and Technology Transfer

2.1.1 Importance of Direct Investment in International Technology Transfer

Increasing worldwide corporate activity is making technology transfer even more complex and difficult to understand. The amount of technology trade between countries is occasionally used as an index to show the amount of technology transfer. However this shows only technology transfers made under licenses. In reality, technology transfer is achieved not by licensing agreements alone, but other factors, such as country-to-country technical cooperation agreements, direct investments by private enterprises, as well as machine exports and provision of guidance and education, are also contributing greatly to the cause. Technology transfers based on licensing agreements and government-to-government technical cooperation agreements can be learned from the statistics, but the modes and effects of other forms of technology transfer are not known. Therefore, some methods to understand the other forms of technology transfer and ideas to analyze them are needed. Overseas direct investment, in particular, is said to play a big role in technology transfer because it enables a plant to be built and managed through manufacturing technology and know-how and transferred overseas as a package in a short period of time. As described in the beginning, Japanese direct investment in East Asia is sometimes said to not only have worked as a motive power for the industrialization in the area countries but also have the effects of technology transfer. However, the cause and effect relationship in this respect has yet to be fully analyzed. Therefore, in our case study, technology transfer will positively be analyzed mainly from the perspective of direct investment to see what technologies have actually been transferred.

Based on the actual facts obtained in the rapidly industrializing East Asia, the interrelations between direct investment and technology will open the bright prospect for solving the technology gaps between North and South.

2.1.2 Correlation Between "Borderless" Corporate Activity and Technology Transfer

The first point to be kept in mind is that the economies of Japan and East Asia are becoming borderless. What the term "borderless corporate activity in manufacturing industry" means in this study is that production activity progresses under a condition that a company from a certain country builds a plant in some other country and the elements needed for the plant's production activity, such as technology, parts, materials, labor, and capital, are obtained by establishing an interchangeable or supplementary relationship between the plant's original country and its host country or a third-party country. In recent years, not only large Japanese companies but also small-to-medium Japanese companies, such as parts makers and subcontractors, have been advancing into East Asian countries.

In the case of manufacturing abroad, even if a final product is manufactured in a country where the foreign subsidiary is established, this does not necessarily mean that all the technology needed to manufacture the product has been transferred to the host country. As the manufacturing technology of parts and components has become highly sophisticated and more important technologically, it is necessary to keep an eye on where the parts were manufactured. With increasingly borderless industrial activity, some of these parts and components come from various sources, such as Japan, the host country or a third-party country. Even when such parts and components are manufactured in the host country, there still remains the question of who manufactured them—the local enterprises or Japanese local subsidiaries? Thus, depending on where a product was produced by an enterprise of what nationality, its parts and components form a complex matrix. Products can be analogous to onions. That is, if you try to peel an onion, i.e., a product, you find that one skin (component) was manufactured in country A, another skin (part) comes from country B, and the final product was assembled in country C. In other words, the origin of products is becoming blurred.

The technological structure being like an "onion," the key to correctly grasping the actual state of technology transfer lies in finding out this: In what way is the technology transfer accompanying a Japanese firm's advance into a third-party country as a base of its overseas production represented in what part of the technological system where the product manufactured locally uses the very technology of the Japanese companies having overseas operations?

In overseas production, how many goods and services a company operating in a third-party country purchased locally—i.e., the percentage of locally procured parts and components that go into a product—is often used as an index showing the country's technical level. However, the following fact needs to be kept in mind when considering the local procurement ratio. The local government insists on maintaining the ratio at a high level due to the dual need of promoting domestic industry and decreasing the trade deficit; but the country's capacity to provide parts and components is not high, and as a result the figure is determined as a product of compromise. Worse yet, the procurement ratio represents only the

overall percentage of the locally procured parts and components that went into a product (a car or electronic appliance, for example), and it does not say anything about the difference in the importance of one part compared to another. For these reasons, we found that the figures for the local procurement ratios that have until now been used in discussing the topics like the procurement ratio were of no direct value to our survey and research objective.

As the yardstick for judging the technical prowess of a country, the important thing is not whether the industrial product was manufactured in that country but where the major parts and components making up the product came from.

2.1.3 Difference Between Inter-Corporation and Intra-Corporation Technology Transfers

Since the process of technology transfer differs greatly depending on if it is taking place in the form of a transfer from a parent company to its overseas subsidiary or if the technology is being transferred from a company in a country to an enterprise in some other country, the question of whether the destination of technology transfer is a Japanese enterprise operating in some other country or someone else is of great importance. Since companies that have established operations overseas have increasingly contributed to the local economies, the advantage of discussing the nationalities of such companies is slight. However, since corporate behaviors regarding the destination of technology transfer—whether a local subsidiary of a Japanese company or someone else—differ greatly, the issue cannot be overlooked.

Granting technology transfer has taken place as a result of the start of overseas production, in many cases it is difficult to say if it is a transfer from one division of a company to another division (intra-corporation transfer) or if it is a transfer from one company to some other company (inter-corporation transfer). The frequency of technology transfer from firms in advanced countries to other firms capitalized locally also must be grasped and analyzed. Direct investment in East Asia by advanced countries dates back to more than 20 years. Industrialization in East Asian countries has advanced greatly, and it is a matter of great interest to study what forms the recent spate of Japanese firms' investments in the area have taken.

Therefore, in our case study attention is paid not only to the technology transfer that increases as overseas production progresses (described in Paragraph 2.1.2) but also to differences in the modes of technology transfer—whether it is intra-corporation transfer by Japanese firms (a typical example is direct investment by a firm into its wholly owned subsidiary) or inter-corporation transfer (a typical example is a technology transfer contract, but seen from the side of enterprises in advanced countries that have technology, all other forms of technology transfer by which the developing countries have obtained technology may be construed as inter-corporation technology transfer). The latter shows which of the technologies that have found their way into East Asian countries are still retained in the hands of Japanese enterprises and which have been transferred to the enterprises in these countries.

2.2 Correlation Between Technological Progress and Technology Transfer

The second point of interest is the correlation between the progress of technology and technology transfer.

Technological advances in manufacturing fields have been remarkable. In analyzing technology transfer, for the following reasons it is important to understand technology as something with a dynamic character that changes constantly and that affects the manufacturing method and the behavior of the enterprise using the technology.

The first reason is that the diminishing life cycle of merchandise is changing the precondition of production: Manufacturing is undertaken in the country that is best suited to the manufacture of the commodity in question. Take electric appliances, for example. The life cycle of merchandise is shrinking rapidly as a result of advances in technology. As life cycles become shorter, so do the equipment depreciation periods, and enterprises will find it difficult to draft a corporate strategy under which plants are shifted elsewhere as the technology matures. On the contrary, from the perspective of how they will be able to establish the most efficient manufacturing system in what place, companies will have to begin with specifying the plant site. The recent spate of overseas production starts by big Japanese corporations is reaching the stage of a simultaneous worldwide production system. For these reasons, the product cycle theory that explains that the generation of technology to its maturity proceeds in stages seems to be losing its effectiveness in the real world.

As described previously, in the machinery industry, an industry where technological innovations have occurred at greater speeds, management is adopting a technology management strategy that is highly geared to the growth potential of new technology. That is, frequent changes have been made in the kinds of items destined for overseas production and on their specifications, and with it, improvements have frequently been made to the parts and components and the machinery and equipment have been adjusted frequently. When the R&D aspect is taken into account, companies must inevitably keep in the country where they are rooted the kind of production technology with high growth because it is where the company's foundation for development exists. Hence, overseas production can no longer exist if unrelated to R&D activity.

Attention must be paid to the fact that with a diminishing product cycle as a result of technological advances, there has been a trend where the progress of

technology transfer is determined by a new factor, i.e., consideration of technology R&D.

Second, advances in technology sometimes change the technological foundation needed for productive activity, and technology transfer can thus be viewed from the point that the changed technological foundation affects technology transfer itself. The growth of microelectronics has led to the development of sophisticated, multifunctional and high-reliability parts and components. The result is that standardization has advanced in electronic parts and components for general household durables such as audio systems, thereby making it possible for the manufacturers to obtain basic parts from the market. Circuit design and tuning, processing technology of the mechanical portions, and organization of a rational assembly process are said to be the source of corporate competitiveness.

These can be considered as the technical conditions that facilitate the international division of labor according to process steps, as described previously. What this means is that manufacturing goods can be started in many countries, regardless of the technological capabilities of the country. The increased overseas production that has ensued has superficially accelerated technology transfer. The technical conditions of the international division of labor has not only prompted companies in advanced countries to start overseas production but contributed to the debut of local industries in East Asia. In the camera industry, for example, parts requiring complex metallurgical processing have been replaced by plastic parts, and the control systems such as exposure and focusing functions have been replaced with electronic circuits including ICs. This technical innovation has enabled the makers in Taiwan and Hong Kong, although the two countries have no metal processing technology foundation, to purchase electronic parts from U.S. and Japanese electronics makers. This line of thinking may provide a clue to solving the previous question why high-tech applied industry has come to take root in East Asia. Reasons for the progress of industrialization in East Asian countries generally include political stability, hard-working people and high educational standards. Apart from this view, we also feel the phenomenon must be discussed from the technical aspect.

We believe it is important to consider the interrelation between technology transfer and technology from the perspective that technology is something transient that continually advances through competition. Therefore, we undertook an analysis of the relationship between the progress of technology and technology transfer. This analysis will give insight into what effects worldwide technological advances will have on the industrialization of developing countries. To be more precise, it will provide a forecast to the question: Will the developing countries be able to catch up with the technological advances in the developed countries?

2.3 Method of Survey and Research

From the foregoing, we decided to conduct a case study of Japanese firms' overseas investment in East Asian countries by using the color TV and camera industries as study materials. We measured the current state of technology transfer that is increasingly taking a complex shape as technological borders between countries continue to diminish, while paying attention to what effects technological advances will have on technology transfer.

2.3.1 Measuring Progress of Technology Transfer—With a View to Parts Procurement Sources in Overseas Production

The idea underlying the case study on the progress of technology transfer is the following.

The fact that a company in one country shifts its production activity to some other country as part of its international division of labor does not mean that all the technology needed for production has been transferred. Here arises the question of how much technology has been transferred. There is as yet no index that can directly show the amount, so the only recourse is to estimate the amount by some means. In our case study, we noted the parts and components for color TVs and cameras, and we judged that regarding parts and components that come from foreign countries, the technology to manufacture them has already been transferred to the countries concerned.

In overseas production, it is very rare for a local plant to undertake manufacturing—from the manufacture of parts and components to their assembly into final products—all on its own; on the contrary, almost all of the parts and components come from sources other than the local plant. Which of these parts and components were manufactured in the local country and which were produced in Japan—this is not known. In our current survey and research project, we planned to reveal the actual state of technology transfer that accompanied overseas production by studying the origins of parts and components and coming up with estimates on where technologies went, what countries they went to, and what were the technologies that found their way into the developing countries.

To this end, case studies were conducted on color TV and camera production in East Asia by the local subsidiaries of Japanese companies. The reason why these two industries were selected is because Japanese TV and camera makers have a long history of overseas production and because in these industries technology transfer is considered to be well advanced.

In connection with Paragraph 2.1, attention was paid to the following points. The first is that what matters is not the product itself but the manufacturing technologies of its major parts and components. The second is that in order to clarify what technology transfer has taken place between Japan and the host country, the parts and components were classified according to their origins,

that is, those produced locally, and those which came from Japan. The third is that in order to study the difference between intra-corporation and inter-corporation technology transfer, the parts and components were classified according to who manufactured them, that is, whether they came from affiliates of Japanese firms or from firms other than Japanese firms or Japanese subsidiaries.

2.3.2 Effects of Technological Advances on Technology Transfer

Based on that described in Paragraph 2.2, consideration was given to the effects of technological advances on technology transfer using the relationships between changes in the technologies for TV and camera parts and components and overseas production.

In order to clarify how the system of parts and components for any specific product has changed, the relation between the product and its parts and components was plotted, resembling a tree (hereafter called a product tree). Furthermore, what changes the increasing overseas production of color TVs and cameras have brought on their parts systems and manufacturing processes were researched and tabulated. Based on the actual state of the processes by which technology transfer progresses in the wake of the start of overseas production, the effects of technological advances on technology transfer have qualitatively been analyzed.

3. Measuring the Progress of Technology Transfer From Parts Procurement

We first sorted out the courses through which technology transfer took place, prompted by direct investment. Next, we tried to measure the current state of technology transfer from the perspective of how the parts and components needed for the overseas production were procured. Case studies of Japanese firms engaged in overseas production in East Asia were conducted, with the targets limited to the color TV and camera industries.

3.1 Routes of Technology Transfer

Before embarking on the analysis of technology transfer, we tried to sort out the methods by which technology gives rise to direct overseas investment. The courses of technology transfer are highly complex and varied. Regarding direct overseas investment, attention must be paid not only to the forms of technology transfer that occur when companies establish their local subsidiaries in the country where direct investment is made but also to various other forms of technology transfer involving inter-corporation technology transfer.

The courses of technology transfer for a case involving an advance by the Japanese electronics machinery industry into East Asia were schematically plotted. In Figure 1, a typical example of the flows of technology transfer accompanying direct investment is shown by solid lines. For reference, the flows of technology transfer based on technology transfer contracts between the Japanese firms and local firms are shown by broken lines. Figure 2, on the other hand, shows the flows of technology among the Japanese parent enterprise, its local subsidiaries, the local-capital enterprise, and the Japanese parts maker's local subsidiaries as a result of their purchasing parts and components from each other. Major courses of technology flow are shown by bold solid lines while the courses of flow of parts and components are shown by bold broken lines. What should be kept in mind in this case is that when the local subsidiary of a Japanese enterprise purchases parts from a local enterprise (A' to C in Figure 2), often the former provides the latter with technical information on the product to be procured, such as specifications, or the former gives technical guidance to the latter, so the transaction may be construed as a sort of technology flow. In this case, the flow of parts and components and the flow of technology are in opposite directions.

In Figure 2, regardless of the destination of technology transfer, be it a firm of the country to which the technology flowed or a local subsidiary of a Japanese firm, technology transfer from Japan to that country is indicated by A → A', A → C, B → B' or B → C.

3.2 Results of a Survey of Parts Procurement; Case Studies of Color TVs and Cameras

As described in Paragraph 2, we tried to measure how effective investment by any specific Japanese industry in foreign countries will be in accelerating technology transfer to those countries, at the parts and components level. We tried to look for a new method to measure technology transfer.

(1) Measuring Method

In our survey of major Japanese color TV and/or camera makers having operations in East Asian countries, we asked them where their assembly plants in those countries were purchasing major parts and components from. Since there is a wide variety of TVs and cameras, we confined our survey to small-size 14- to 18-inch color TVs and compact cameras, where the shift of production bases from Japan to those countries is well underway. In the survey, 11 types of color TVs and 16 types of cameras were selected (Figure 4), and in the questionnaire survey that we conducted, we examined each of the parts and components as to its original country and the nationality of the firm that manufactured it. The survey was taken from May to October 1990, and was conducted by directly hearing from the person in charge at each firm. Regarding the survey method, we selected, from among the overseas plants of the Japanese companies selected, those that met our survey objectives and asked about the sources of each of the parts and components that they had purchased (Figure 5). Since the how, where and when of such purchases are mostly corporate secrets, we could not expect to get the full picture, but we did our best to learn the actual state of such transactions in detail and yet quantitatively.

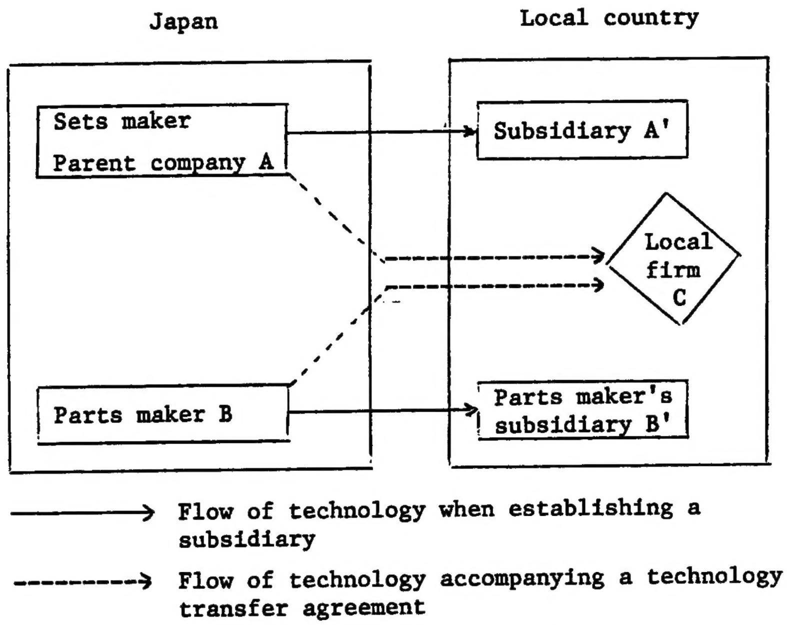


Figure 1. Schematic Diagram of Technology Transfer Accompanying Firms' Overseas Investment (1)

Two forms of technology transfer, one involving a technology transfer accompanying a parent company's establishment of a local subsidiary and the other involving a technology transfer as a result of granting of a technology licensing agreement with a local capital enterprise.

In our survey, the parts procurement degree was quantified by the following method. The number of plants in each industry selected for the survey was used as the denominator, the number of plants deemed as specific sources of procurement was used as the numerator, and the ratio was multiplied by 100. This relationship can be expressed by the following equation:

$$Y = X/N \times 100$$

where N is the number of plants targeted for survey for a single type of part and X is the number of plants specified as the source of procurement of the same type of parts described above.

The procurement degree was calculated for each type of part and component. Here let's consider a specific type of part. Needless to say, the total degree by which a specific part is procured from one classification and the degree by which the same part is purchased from the other classification equals 100. For example, the procurement degree by nationality, described in Figures 6 and 8, shows the distinction between the procurement sources, that is, it says whether the part concerned came from Japan or another country (countries). The procurement degree from Japan is calculated by using the number of plants which purchased the parts in question from Japan as the numerator and the number of plants surveyed as the denominator. The total procurement degree from Japan and from the other country (countries) is 100.

Suppose that a certain plant is purchasing the same part from multiple sources. It is difficult for the plant to accurately say how many parts it has purchased from one supplier and how many from another. In such a case we asked the respondents to name the providers of the parts in order of the largest to the smallest supplier. The ratio of how much the plant has procured from what provider was calculated based on the following assumptions. We assumed that if the plant had two suppliers, two-thirds of the parts came from the larger supplier and one-third came from the second supplier; if the plant had three suppliers, four-sevenths of the parts came from the largest supplier, two-sevenths came from the second largest supplier and one-seventh from the last. The idea behind this formula was to make the total of the geometric ratios equal the numeral 1. The above figures were selected after taking into account the characteristic features commonly observed in the studies. When the plants purchased the same part from several sources, with respect to how those plants ranked the parts suppliers on which they relied, the following tendencies were observed.

1) In most cases, the first-place supplier accounted for more than one-half the total parts that the plant purchased, and the second- and third-place suppliers provided relatively smaller ratios.

2) The distinction between the largest supplier and the second largest supplier and between the second largest supplier and the third largest supplier were clear-cut.

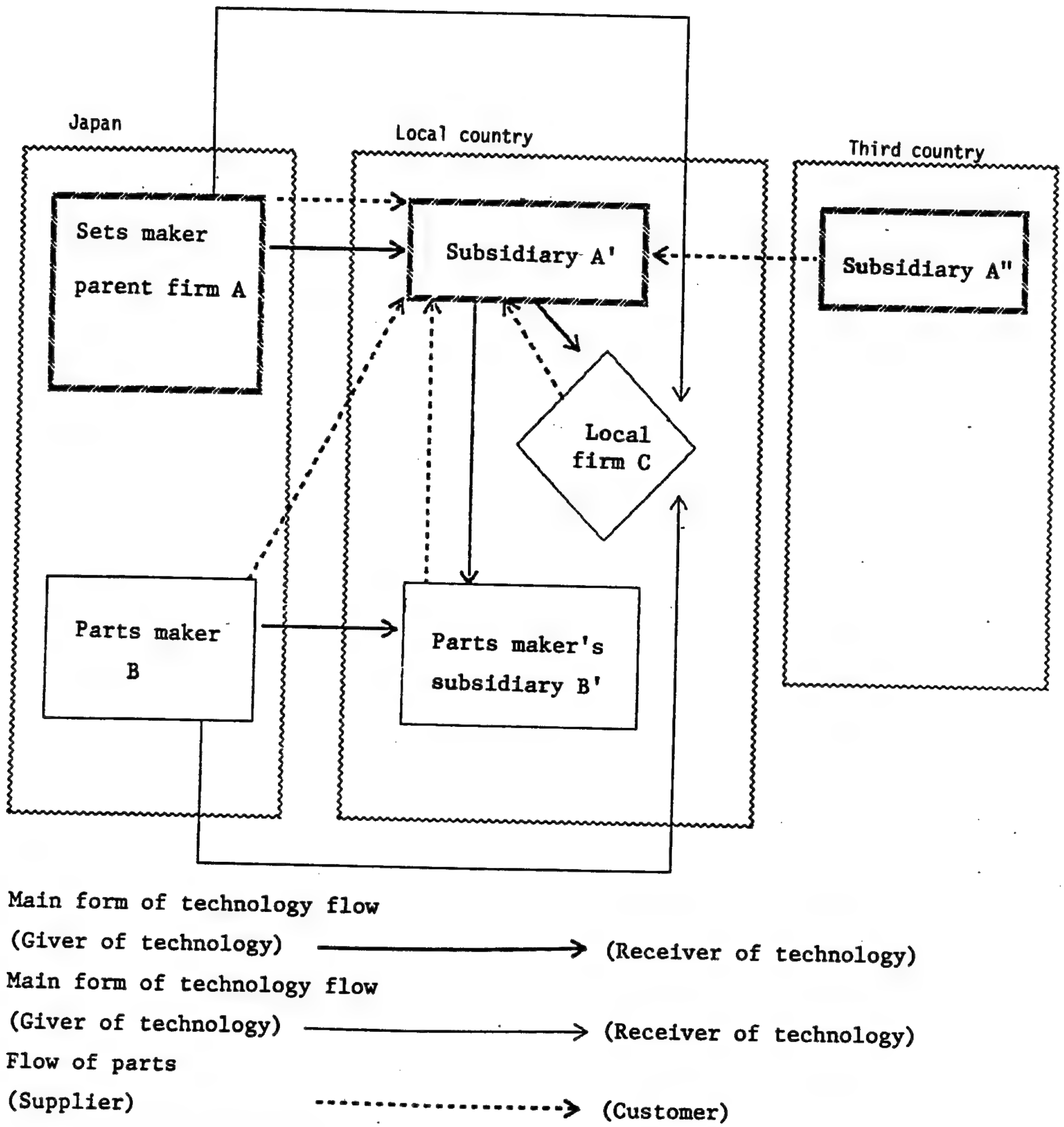


Figure 2. Schematic Diagram of Technology Transfer Accompanying Firms' Overseas Investment (2)

Flow of technology accompanying procurement of parts by the local subsidiary (A')

From 1) above, the first-place supplier was credited with supplying the plant with more than one-half of the parts; from 2) above, it was judged that a rational distribution of the ratios could be seen by differentiating the first-, second- and third-place suppliers by the same ratio; the percentage points for the first-, second- and third-place suppliers were differentiated by a geometric ratio.

In the initial stages of the survey, the parts and components suppliers were divided into nine groups but they were subsequently consolidated into two groups (Figure 5).

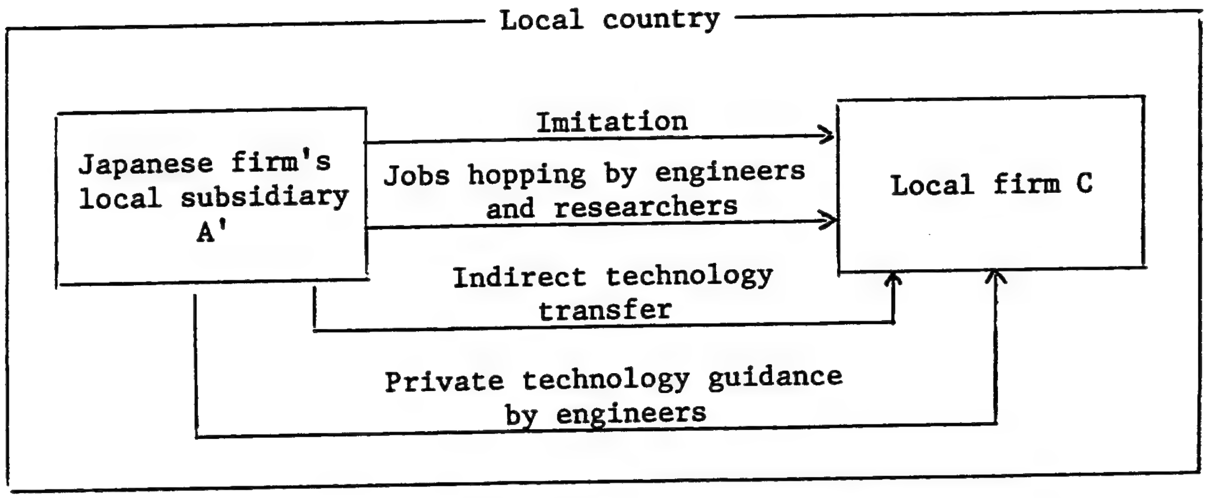


Figure 3. Schematic Diagram of Technology Transfer (3)

Various forms of technology transfer from Japanese subsidiaries established in a foreign country to the local firms (non-typical technology's diffusion and leakage)

(1) Color TVs (the below listed 11 kinds of parts)	(2) Cameras (the below listed 16 kinds of parts)
1. IC	1. IC
2. Transistor/diode	2. Chips
3. Tuner	3. Distance-measuring sensor
4. Flyback transformer (expressed as FBT in the figure)	4. Flexible printed circuit board
5. Deflection yoke	5. Diaphragm horn
6. Braun tube (expressed as CRT in the figure)	6. Prism
7. Printed circuit board	7. Outer cover
8. Condenser	8. Plastic lens
9. Resistor	9. Lens
10. Coil/transformer	10. Tube
11. Cabinet	11. Micro-motor
	12. Plastic core
	13. Spool
	14. Gear
	15. Strobo unit
	16. Liquid crystal display

Figure 4. Color TV and Camera Parts Surveyed

(2) Results of a Survey on Color TVs

Figure 6 shows from what country or countries the local plants of two Japanese electronics manufacturers producing color TVs (mainly 14-inch TVs) in East Asian countries purchased the parts and components for their production activity. The portions marked by oblique lines on the upper tier show the procurement from countries other than Japan (all the East Asian countries) and the black portions on the lower tier show procurement from Japan. The "parts" on the axis of the abscissa are listed, left to right, according to size of their procurement from Japan in descending order.

(1) Classification of Supplier Countries of Parts Used in Survey Through Hearings

Country from which procured	Nationality of the firm from which procured	Code
Local country	One's own subsidiary manufacturing parts in the local country	11
	Japanese-affiliated parts firms	12
	Local-capital firms	13
Japan	One's own company	21
	The assembly firm's affiliates (subsidiaries)	22
	Unaffiliated parts firms	23
Third-party countries	The assembly firm's affiliates	31
	Japanese-affiliated parts firms	32
	Local-capital firms	33

(2) Where the Parts Came From Were Classified Into the Following Categories

a. Classification according to what country the parts were procured from -- Japan or some other country (other East Asian countries)? (figures 11 and 13) Of the divisions in Figure 5-(1), the code numbers 21, 22 and 23 apply to Japan while other codes apply to other countries.

b. Classification according to the nationality of the firms from which the parts were purchased, that is, were they subsidiaries of Japanese firms or non-subsidiaries of Japanese firms? (figures 12 and 14) Of the above divisions, all codes except 13 and 33 apply to the former while codes 13 and 33 apply to the latter.

Figure 5. Classifying Parts Procurement by Country

The graph shows that in the overseas production of color TVs, the number of parts that must come from Japan is not so large and that shifting the role as the supply source away from Japan to East Asia is well advanced. The analysis is not so accurate in quantitative terms but when the procurement from Japan for all kinds of parts is averaged, it comes to 43 percent.

Second, the amount of parts and components made in Japan differs greatly from one type of part to another. When all parts purchases from Japan were listed in descending order, all ICs came from Japan and almost all transistor diodes were also imported from Japan. The dependency on Japan as the supply source for tuners, flyback transformers (high voltage transformers) and deflection yokes (electromagnets for applying an electromagnetic field to electron beams in a Braun tube) declined, reaching about the same level for all other countries combined. The greater portion of the CRTs (color Braun tubes), printed circuit boards and condensers were procured from countries other than Japan. Almost all of the resistors and coil transformers came from countries other than Japan, and cabinets were all procured in countries other than Japan.

Figure 7 also gives a breakdown of the suppliers of parts and components for color TVs. However, no consideration is given to where the parts were purchased, but a distinction is made according to the difference in the nationality of the suppliers, that is, if the suppliers are Japanese-affiliated firms or not. The portions shadowed with oblique lines on the upper tier shows the procurement levels from firms other than Japanese-affiliated firms, while the black portions on the lower tier represent percentage points of purchases from Japanese-affiliated firms. For ease of comparison, the parts are

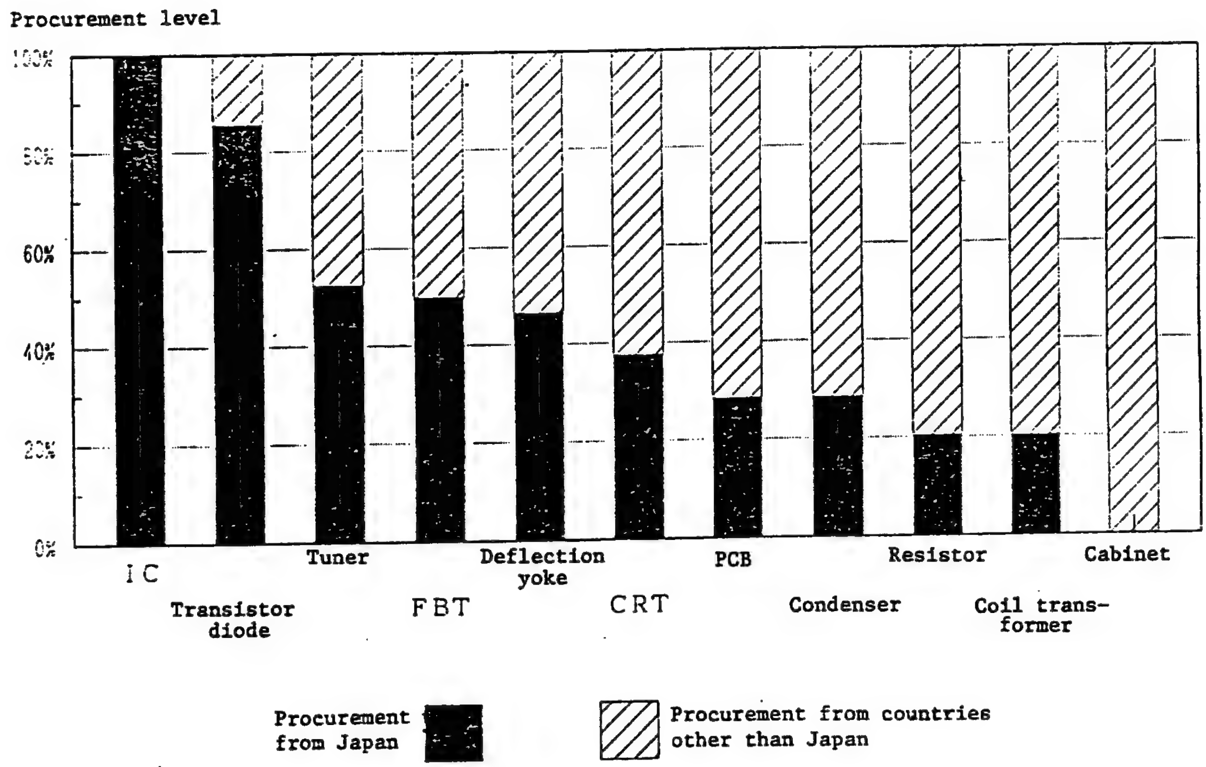


Figure 6. Levels of Parts Procurements From Japan in Overseas Production of Color TVs (by two major Japanese firms)

listed in the order as described in Figure 6. The graph shows that the amount of parts and components purchased from non-Japanese-affiliated firms is almost nil. Only cabinets, CRTs, printed circuit boards, and deflection yokes were procured from suppliers other than affiliates of Japanese firms, but the ratios of these purchases to the total purchases are small.

The big difference between Figure 6 and Figure 7 is that in the former the purchases of parts and components from countries other than Japan account for larger parts of their total purchases, but in the latter, purchases of parts and components from suppliers other than affiliates of Japanese firms are almost nil. This difference seems to suggest that divisions of leading Japanese electronics manufacturers and Japanese makers of parts and components are already established in East Asian countries and that Japanese-affiliated assembly plants in those countries have been procuring parts and components from those local operations. This explains why purchases from non-Japanese-affiliated firms, especially companies capitalized locally, are so small.

(3) Results of a Survey of Compact Cameras

Figure 8 gives a breakdown of from what country or countries the subsidiaries of three Japanese camera makers who manufacture cameras in East Asian countries purchased the parts and components for their products. Sixteen kinds of parts and components are listed. As with Figure 6 for color TVs, the portions marked by oblique lines on the upper tier show the parts purchased from countries other than Japan (all the East Asian countries) and the black portions on the lower tier show the parts purchased from Japan. The parts are listed according to size of procurement from Japan in descending order.

The graph shows that the cameras produced in East Asia have made-in-Japan parts at a much higher percentage rate than the comparable figures for color TVs. Averaged, 71 percent of all 16 kinds of parts came from Japan.

By parts type, ICs, chips and distance-measuring sensors all came from Japan; larger portions of the flexible printed-circuit boards, diaphragm horns, prisms, lenses and tubes were imported from Japan, in descending order; and purchases of plastic cores, gears, spools and strobo units were about equally split between Japan and the other countries.

Figure 9 gives a breakdown of the suppliers of camera parts by country. As with Figure 7, the yardstick for

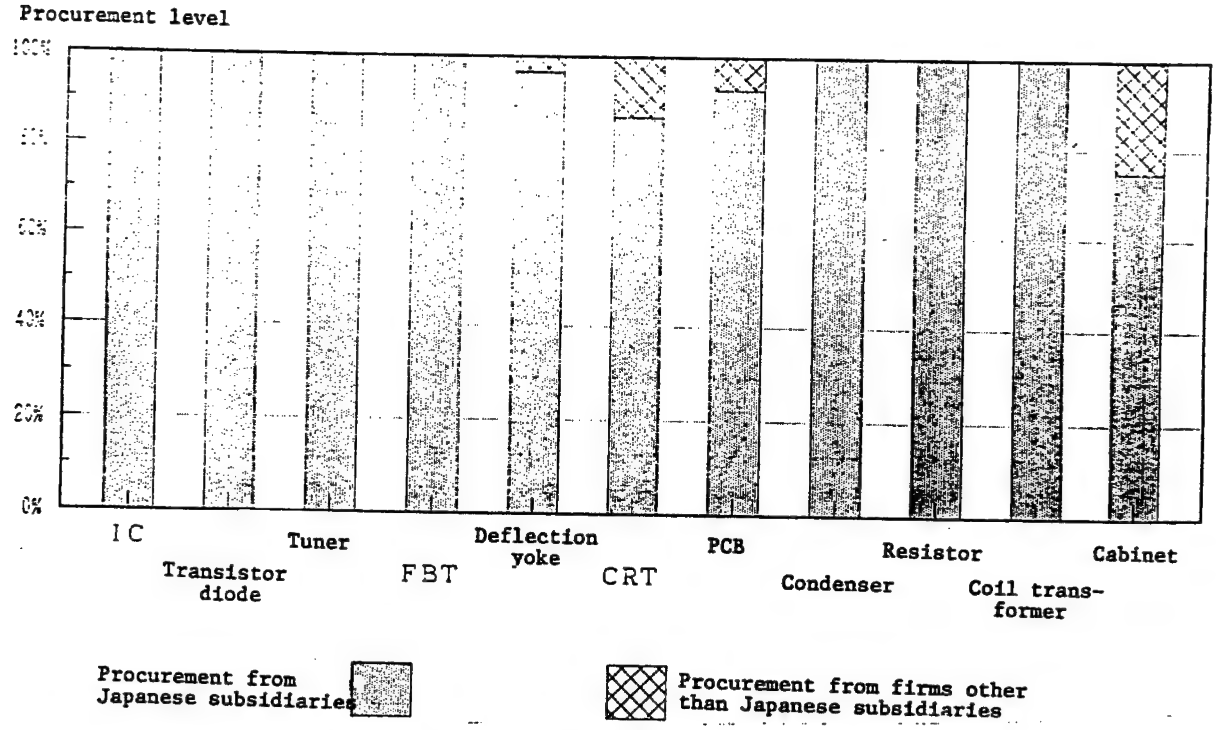


Figure 7. Levels of Parts Procurement From Japanese Subsidiaries in Overseas Production of Color TVs (by two major Japanese firms)

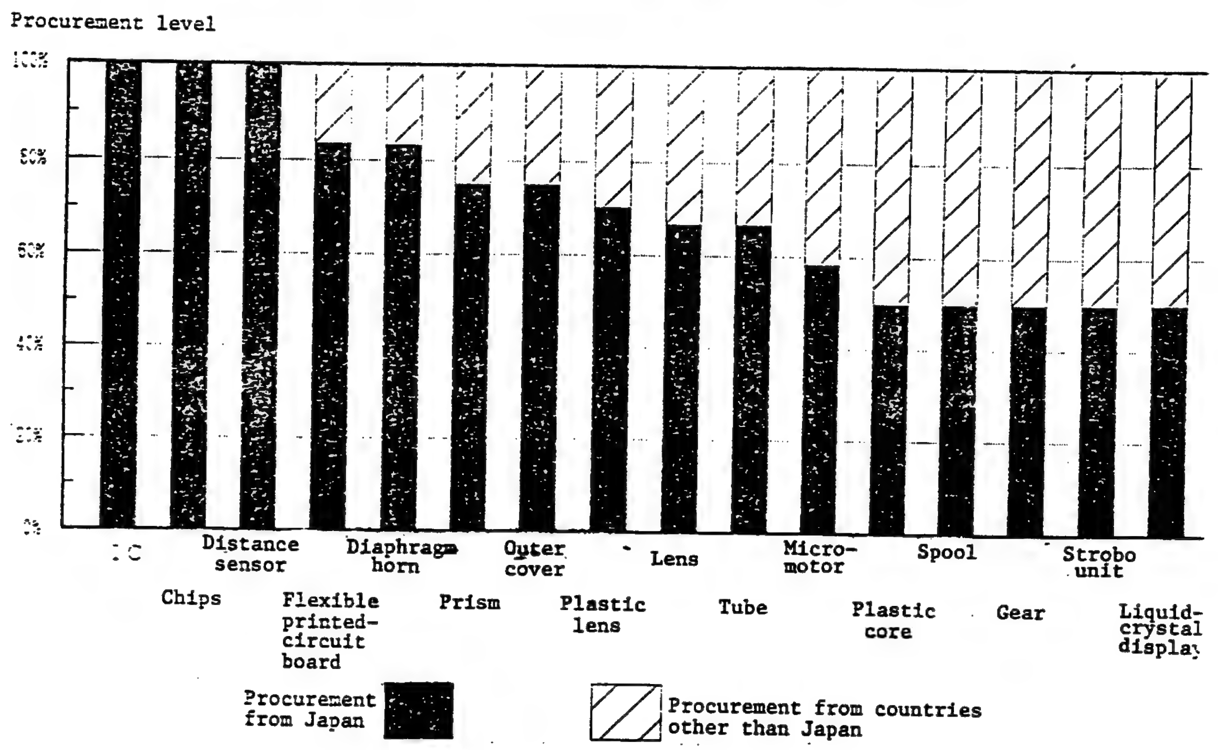


Figure 8. Levels of Procurement of Parts From Japan in Overseas Production of Cameras (by three leading Japanese firms)

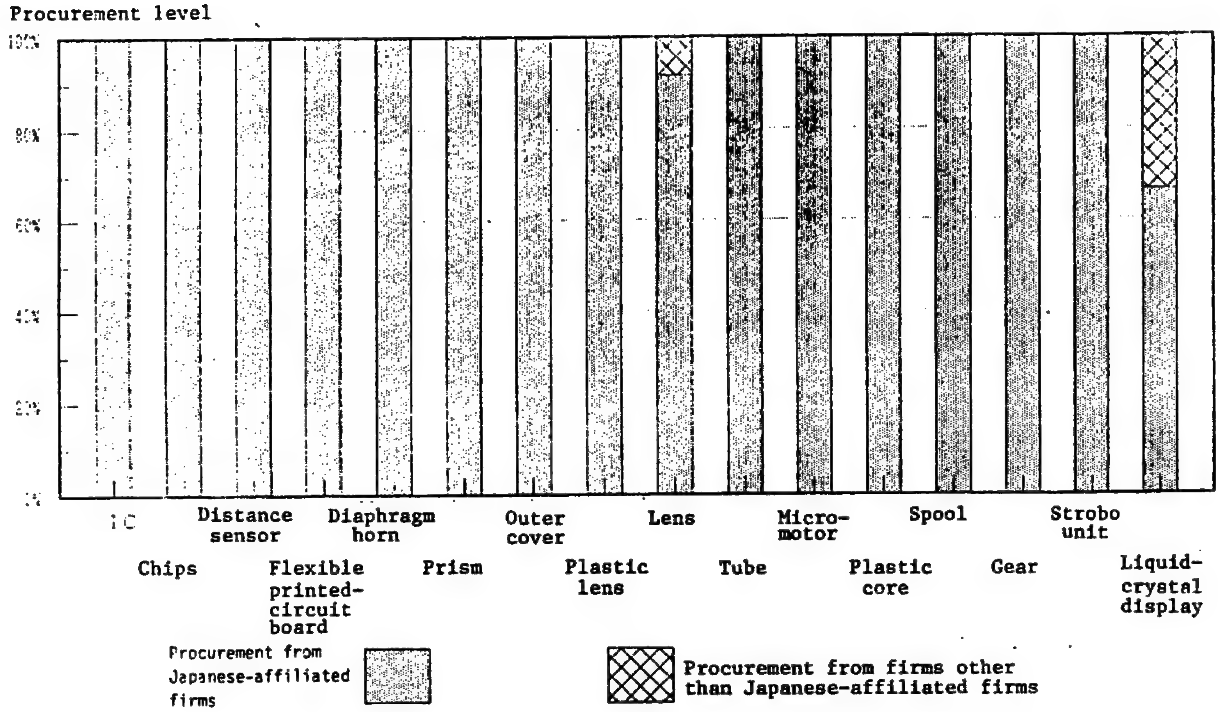


Figure 9. Levels of Procurement of Parts From Japanese-Affiliated Firms in Overseas Production of Cameras (by three leading Japanese firms)

differentiation is whether the supplier is a Japanese subsidiary or not; what country the Japanese subsidiary is located in is irrelevant. The portions shadowed with oblique lines on the upper tier show the levels of procurement from firms other than subsidiaries and affiliates of Japanese firms, while the black portions on the lower tier represent the percentage points at which parts were purchased from Japanese firms and/or their subsidiaries. As in Figure 8, parts are listed in descending order. Trends similar to those in Figure 7 for color TVs are observed. Except for liquid-crystal displays and lenses, almost all of the remaining types of parts were purchased from Japanese-affiliated firms. This seems to suggest that Japanese-affiliated manufacturers of machine parts and electronic parts have operations in East Asian countries and the local assembly plants of Japanese firms have been procuring parts from the local operations of these Japanese-affiliated makers.

(4) Comparison Between Color TVs and Compact Cameras

The first comparison regards the origin of the parts and components, that is, what country or countries they were procured from, Japan or other countries? (Figures 6 and 8) The ratios of camera parts which were purchased from countries other than Japan are smaller than the comparable figures for color TV parts. The reasons for this are believed to be the following: First, since assembly of cameras is highly labor-intensive, the overseas plants of the Japanese camera makers were expected to undertake only assembly operation; second, the peripheral companies manufacturing high-precision parts are mostly small-scale, so they were hardly able to set up operations in foreign countries; and third, besides being small in size and demanding high precision, cameras are subject to frequent design changes, so it was probably considered advantageous to manufacture camera parts and components in Japan.

Next, as for the nationality of the firms from which parts were purchased, that is, whether they are Japanese or Japanese-affiliated firms, or firms other than the above Japanese or Japanese-affiliated firms, Japanese and Japanese-affiliated firms overwhelmingly predominate for both color TVs and cameras (Figures 7 and 9). The localization of procurement of parts is progressing only in the form of Japanese and Japanese-affiliated parts makers' advances into the local markets. The reasons for this are probably the lower technological standards at the local firms, the extremely rigorous specifications demanded regarding the precision of parts, and the Japanese TV or camera makers' strong kinships with their satellite companies.

For both TVs and cameras, electronic parts lie at the top of the list of items which are mostly imported from

Japan: these are ICs, and transistor/diodes in the case of color TVs and chips and distance sensors for cameras.

(5) Conclusion

The foregoing can be summed up as follows: 1) As for the sources of procurement, parts are increasingly being purchased from, in addition to Japan, other countries (including the countries where the Japanese companies have operations, and third-party countries). Japan's position as the supplier of camera parts is high, but it has a lower profile in the case of parts for color TVs. 2) For both TVs and cameras, almost all of the purchases of parts are with Japanese and/or Japanese-affiliated firms. 3) There are differences in the levels of procurement from Japan according to the type of part.

3.3 Consideration on Technology Transfer

How technology transfer from Japan to East Asia has progressed can be inferred from the state in which parts were procured from countries other than Japan, given in Figures 6 and 8. As was described in Paragraph 3.1 "Routes of Technology Transfer," the fact that parts were purchased from countries other than Japan means that those countries have the capability to manufacture those products, and this in turn implies that some kinds of technology transfer to East Asian countries have taken place. The technology transfers may have come from other advanced countries beside Japan. However, when the strong influence that Japanese technology has in East Asia, especially in the color TV and camera fields, and the fact that the purchases of parts were made by Japanese firms are taken into account, the possibility is very high that the technology transfers came from Japanese enterprises. So, the aforementioned possibility that the technology may have been provided by other advanced countries is discarded here.

In Figure 2, the routes of technology transfer to the local-capital company C are represented by A' → C, A → C, and B → C. The A' → C route is one in which procurement of parts comes together with providing a great deal of technological guidance and cooperation. The remaining routes are considered to involve mostly licensing agreements. How these types of technology transfers have taken place can be inferred from Figures 7 and 9 which show the state of procurement of parts from firms other than Japanese firms and their affiliates.

From the aforementioned state of procurement, we can assume the existence of the following two forms of technology transfer: 1) technology transfer from Japan to an East Asian country accompanying the start-up of local production there; and 2) technology transfer to a non-Japanese-affiliated firm or firms as a result of the start-up of local production by a Japanese firm. Those sections shadowed by oblique lines in Figures 6 and 8 represent the form of technology transfer given in 1) above, while those marked by oblique lattice patterns in Figures 7 and 9 show the form of technology transfer given in 2) above.

In 1), technology transfer for color TVs is progressing smoothly; about half of the parts now comes from countries other than Japan. Technology transfer for cameras is also progressing but is slower than that for color TVs.

Regarding technology transfer from Japan to East Asia, shown by oblique lines in Figures 6 and 8, two cases can be considered: One is technology transfer to Japanese firms that have started operation in the local country and the other is technology transfer to non-Japanese firms (mainly local enterprises). The sections marked by oblique lattice patterns in Figures 7 and 9 that show the technology transfer 2) show technology transfer to non-Japanese firms. In Figures 7 and 9, those sections marked by oblique lattice patterns make up only a fraction of the area, revealing that such a form of technology transfer rarely occurs.

Let us here study the two pairs of figures, Figures 6 and 7 for color TVs and Figures 8 and 9 for cameras. In each pair, those sections marked by oblique lines and those marked by oblique lattice patterns differ greatly in size. From these sections representing technology transfer from Japan to East Asia, we can learn that most of the technology transfers have taken place between Japanese-affiliated firms with each other. In short, most of the technology transfers have taken the form of technology transfer from Japanese firms to Japanese-affiliated firms having operations in East Asian countries, and technology transfers from Japanese firms to non-Japanese-affiliated firms are few.

3.3.1 Intra-Corporation Technology Transfer Progresses Differently From One Technology to Another

Transfer of parts-manufacturing technologies accompanying the start-ups of assembly operations in East Asian countries has mostly been realized by advances into local markets by Japanese parts makers. In other words, for those Japanese firms involved, the international technology transfer has basically been technology transfer within the same corporation. Differences in the form of technology transfer among various parts technologies are examined in conjunction with the characteristic features of each of those technologies (required manufacturing equipment and the speed of technology development). Parts manufacturing technologies are classified according to stereotypes, and each stereotype is examined in conjunction with the trends of technology transfer derived from the patterns of procurement of parts (Figure 10).

Figure 10-1. Relationship Between the Progress of Technology Transfer and the Technology's Features in Color TV Production

Technology division	Technology transfer level	Technology's characteristics	
		Need for equipment investment	Speed and characteristics of technology development
1. Design and development	None	Small	Fast
2. Assembly technology (assembly machinery operation, repair and quality control)	High	Large	Fast. Automation is well advanced.
3. Semiconductor manufacturing technology	Low	Large	Fast. Design technology is important.
4. General electronic manufacturing technology	Medium	Varied	Not so fast
5. CRT and peripheral parts manufacturing technology	Medium	Large	Not so fast. But, technological innovation of large-size CRT is very fast.
6. Formed parts manufacturing technology	High	Small	Not so fast. High-precision dies for plastic molds require experience and technique.

Figure 10-2. Relationship Between the Progress of Technology Transfer Abroad and the Technology's Features in Camera Production

Technology division	Technology transfer level	Technology's characteristics	
		Need for equipment investment	Speed and characteristics of technology development
1. Design and development	Low	Small	Fast
2. Assembly technology (assembly machinery operation, repair and quality control)	High	Small	Not so fast. However, automaton is being promoted in inspection and adjustment fields.
3. Semiconductor manufacturing technology	None	Large	Fast. Design technology is important in IC. Innovation of manufacturing machinery is fast.
4. Plastic formed parts manufacturing technology (gears, film-winding devices, etc.)	Medium	Small except die manufacture	Not so fast. Requirements for high precision are stringent. Precision dies for plastic molds require experience and technique.
5. Metallic parts manufacturing technology (tubes, shutter parts, screws, etc.)	Low	Large	Varied
7. Optical parts manufacturing technology	Low	Investment needed for automation of lens production. Skilled labor is the key to prism production.	Not so fast. The speed of R&D for automated operation of lens production is fast.

1) Except for a single Japanese camera maker, none of the Japanese firms that have established their base of production in East Asian countries have undertaken design and development work locally. Leading Japanese electronics manufacturers have designated Japan as the center for design and research, and the transfer of such a function to East Asia is not progressing.

2) Technology transfer is not progressing in the IC and chip fields. These products are highly research-oriented and their production requires large amounts of investment in equipment.

3) Transfer of technologies for general parts and components is progressing smoothly. The pace of technological innovation in these products is not so fast, and there seem to be few obstacles to technology transfer.

—Transfer of technologies for Braun tubes and their peripheral parts is progressing smoothly. The pace of technological innovation for small-size Braun tubes is slowing down.

—Transfer of technologies for the general type of resistors and coils whose technological innovation is not fast is progressing smoothly.

—Transfer of technologies for formed parts such as cabinets, film-winding parts, metal fittings is completed. However, high-precision formed parts for cameras and parts which are subject to frequent design

changes are mainly produced in Japan. It seems the technological levels of overseas plants are low in terms of both the high-precision machining abilities and the capacity of machinery and equipment.

—Transfer of technologies for optical parts is not progressing. Although these technologies have already reached the level of maturity, they demand skilled labor.

4) Transfer of assembly technologies is progressing smoothly. It seems advances in the sophistication of parts and the progress of automated assembly have eased assembly according to manuals, thereby making it easier to transfer technology. Also, software technology such as production control has taken root in East Asian countries.

3.3.2 Inter-Corporation Technology Transfer Progresses Slowly

Even when procurement from Japan dropped, the diminished purchases have not had any effect on shifting production to the local firms or to expedite technology transfer. Therefore, the trend as to what parts are consigned to other firms for manufacturing in what order are unknown. It may be that Japanese-affiliated firms have established their own networks of procurement and these networks function as a sort of "wall" beyond which technology transfer never progresses.

One reason why technology transfer to non-Japanese-affiliated firms is so hard to come by is the technological gap between Japanese firms and local firms and an element causing the further expansion of this gulf—the difference in the speed at which information can be accessed. Manufacturing technologies of such electronic parts as ICs, chips and distance sensors—the very products whose supplies come mostly from Japan—have become extremely sophisticated in terms of automated production, high-density packaging, higher reliability and lower cost, and thus the wall is very high for any neophytes trying to penetrate the market.

Besides technology transfers which are finalized through an understanding of the firms having technology, such as those based on technology transfer contracts and dispensing technological guidance accompanying procurement of parts, there may be other forms of technology transfer that accompany the start-ups of overseas production (Figure 3). These flows of technologies that are transferred beyond the "wall" may be generically called technology "leaks." If this technology leakage is to have any great effect, firms in the developing countries are called upon to obtain and accumulate technology by means given in Figure 3. Local governments are encouraged to adopt policies to train technical people, and firms in the advanced countries are asked to undertake technically advanced operations such as design work and research and development.

3.4 Supplementary Comments on the Survey Results

It is necessary to add some additional comments on the results of this survey.

First, our current survey targeted only two industries, and the samples were extremely small in number—three from the camera industry and two from the color television industry. Because our survey demanded in-depth studies, it was difficult to increase the number of samples. We believe our survey method was effective in bringing to light the actual trends of technology transfer to some extent.

Second, the parts targeted for analysis in our survey all are critically important in the structures of the products incorporating them and furthermore embody high levels of technological sophistication. If trends can be found regarding the procurement of parts of lesser importance, results could be different from those in our current survey. At the extreme, metal fittings in color TVs and their packaging materials, springs and screws for cameras may have been procured from countries outside of Japan and from non-Japanese-affiliated firms at extremely high levels.

Third, the original goal of our survey was to study technology transfer that resulted from Japanese firms' advances into six countries or regions in East Asia, and the result was that South Korea was not one of the countries in which the Japanese firms surveyed were represented. Therefore, this survey, in a strict sense, addressed the following five countries or regions, i.e., Asian NIES excluding South Korea, Thailand and Malaysia. Since South Korea has aggressively been promoting its own industrialization program, the situation there may differ from other countries.

4. Effects of Technological Advances on Technology Transfer

We have observed the process of technology transfer accompanying the start of overseas production and analyzed the effects of technological advances on technology transfer. First, in the following is given an overview of technological advances in the color television and camera industries. Next, we will examine what relationships exist among the technology transfer, technological advances and the progression of international division of labor, followed by in-depth consideration of what the key elements in the analysis are.

4.1 Advances in Manufacturing Technology of Color TVs and Cameras

Distinctive features underlying advances in the manufacturing technology of color TVs and cameras are sorted. The same TV and camera models as the ones described earlier were selected for our current work. Among the developments featuring changes in the manufacturing technology of color TVs are the development of transistors and ICs, increases in the functional capabilities of electronic parts and components, automation and labor-saving in the assembly process. Similarly, changes in the manufacturing technology of cameras are characterized by a change in the functioning of cameras from mechanical to electronic operation, adoption of

plastic materials, modular assembly, automation in manufacturing of individual parts and components, and computerized design work.

4.1.1 Changes in Product Trees

(1) Color TVs

To help the reader understand a system of parts and components comprising a color TV, Figure 11 shows a product tree for color TVs which relates the links between a product and its components. A color TV as the final product is depicted on the left side of the tree, and to its right branch the components of the product. Accessories are depicted at the top, parts for the CRT are in the middle, and parts for the electronic circuitry are listed at the bottom.

Components indicated by broken lines show their technological state 20 to 30 years ago and each component's current state is given by the component in a parenthesis that follows. The tree reveals that the old vacuum tubes have been replaced by transistors and several electronic circuits by ICs. A 14-inch color TV contains six to 10 ICs. (The color TV in the figure contains eight ICs.) A single IC can perform a specific function that was conducted in the past by a circuit made up of several tens of devices (these circuits are identified by broken lines). Wires that were used to interconnect circuits and parts have disappeared as a result of the development of printed-circuit boards. The resulting incorporation of high technology in the components themselves has greatly contributed to the simplification of the parts system.

(2) Cameras

Figure 12 gives a product tree for compact cameras. Technological innovation in cameras has rapidly advanced in the past 20 to 30 years. Introduction of electronic technology in the making of cameras has resulted in the replacement of a large number of conventional precision parts that required mechanical machining by electronic circuits like ICs. According to the manufacturers of cameras, electronic circuits were rarely found in the old cameras, but in the present compact cameras 40 percent of the total number of parts is electronics, amounting to about 50 percent of the total value of the parts. Introduction of plastic forming technology has progressed in keeping with increased strength and improved aesthetics of plastic materials, and since about 1965 plastics have come to be used in external components. This was followed by their application in the bodies and internal components of cameras, and plastic lenses are now widely used. Plastics are suitable for fabricating parts of complex shapes and hence are considered to have contributed to reducing the number of parts and components. However, cameras as a whole have gained new capabilities which require new components, so a camera of today does not necessarily have a greatly reduced number of parts and components compared to a similar product of 20 years ago.

4.1.2 Process Innovation

The following describes examples of changes in the manufacturing process.

(1) In the case of color TVs, automation in assembly can be cited as the greatest change. In the manufacture of 14- to 15-inch color TVs, several hundred to 1,000 electronic parts are automatically mounted on a printed substrate and soldered at extremely high speed. In the initial stages, this packaging job was done using primitive machines, which required lots of manpower. Due to increases in the performance of automated insertion machines and advances in the standardization of components' shapes, the percentage of parts mounted by automated insertion machines has exceeded 90 percent, thereby realizing great savings in manpower. The emphasis in assembly process has shifted to how to operate the automated packaging machines, how to maintain and check them, and how to ensure a sure supply of parts bonded on tape.

The advent of simplified circuits and the standardization in the size of devices have made assembly work by automated packaging machines possible, resulting in decreased steps in assembly operation and inspection work. This is believed to have led to a simplified assembly operation. Advances in the automated manufacture of electronic components have enabled their supply in large lots, and this is the key supporting automated assembly. Advances in overseas production have been progressing side by side with such phenomena as described above. These technological advances have facilitated the manufacture of high-quality products abroad.

(2) In cameras, the widespread use of plastic forming technology has led to a simplification of the parts manufacturing process (Figures 13 and 14). When metallic parts were used, the process for their machining required a widely varied and complex operation. That is, the machining operation began with the pressing and cutting of the metals, followed by grinding and finishing touches. After these steps were completed, the metal products were further subjected to surface treatment and plating or coating. However, the advent of formed plastic parts has eliminated the need for the aforementioned steps associated with metallic machining. With increasing use of plastic components in cameras, the work load that otherwise would have been needed has been diminishing step by step. Again, the use of plastic components is contributing to the simplified assembly process through decreased number of parts needed for a camera.

The widespread adoption of electronics is also greatly changing the manufacturing process of cameras. Needless to say, in the past cameras were made up of high-precision mechanical parts, but from about the 1960's, combination exposure meter-shutter systems and electronic shutters have increasingly been used and at present almost all of the major control functions are

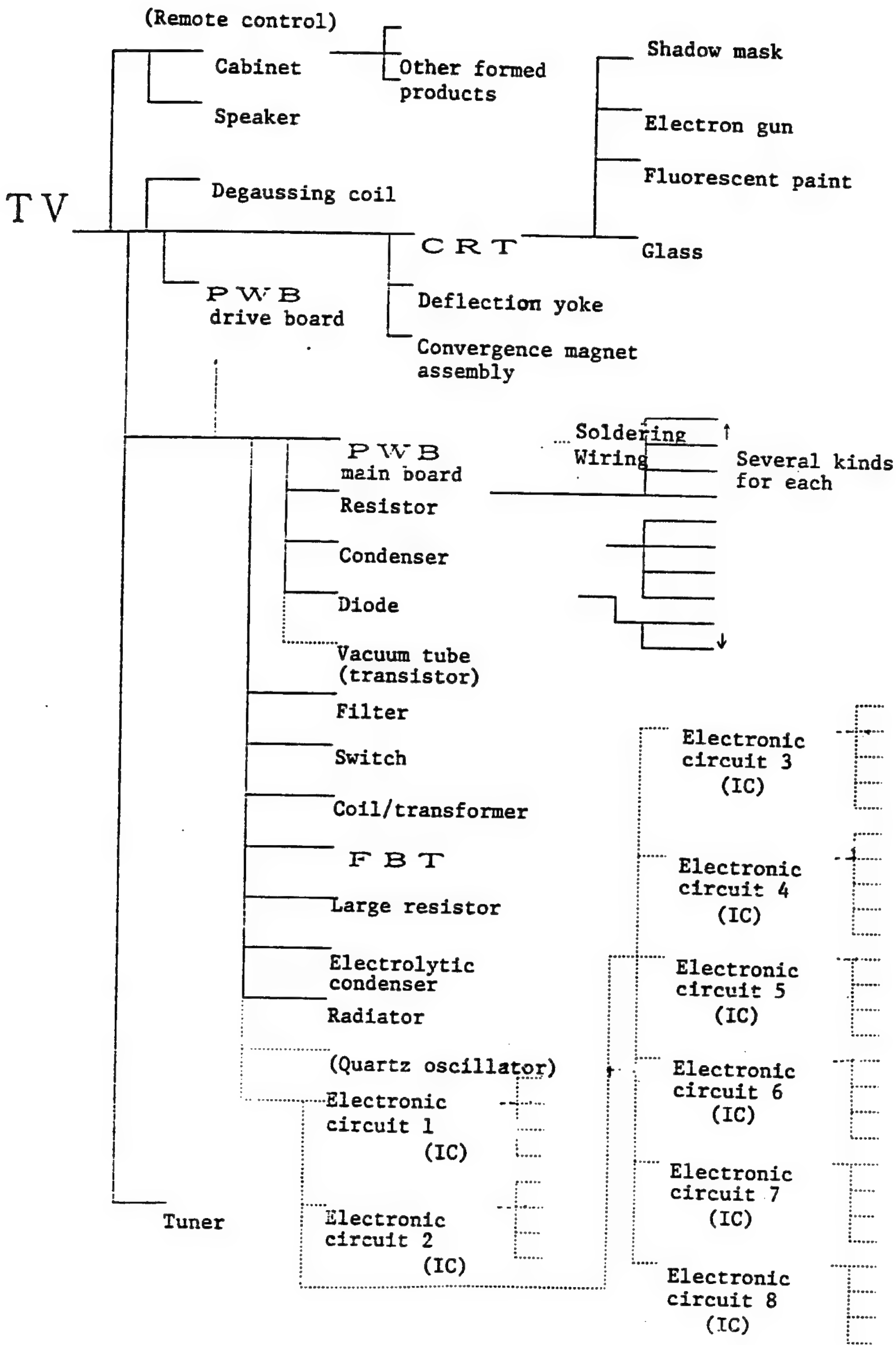


Figure 11. Product Tree for Small Cameras (parts system diagram) (Broken lines show past state, and parentheses show present state)

Unit — Discrete component

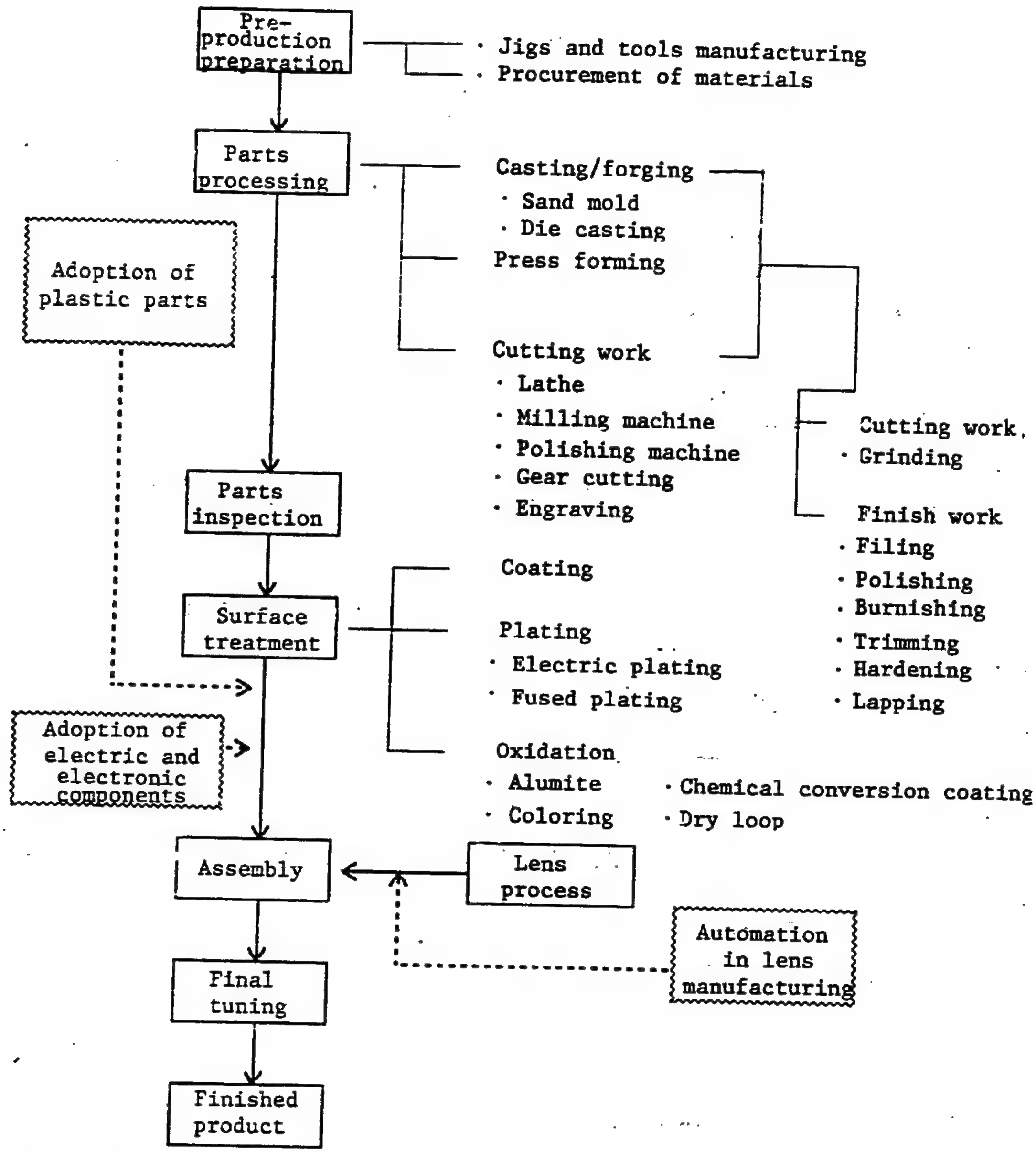
- Compact camers
  - Body (core)
    - Plastic formed core (*)
  - Film winder/rewinder
    - Gear (*)
    - Spool (*)
    - Motor
  - Lens unit
    - Lens (***)
    - Tube (****)
    - Shutter (**)
      - Diaphragm horn (****)
    - Distance meter (**)
      - Distance sensor (**)
    - Electronic circuit (**)
      - Flexible PWB
      - Electronic parts
        - ICs
        - Chips
          - Exposure, AF, display functions
  - Strobo unit
    - Strobo discharge tube
    - Coil
    - Condenser
  - Finder unit
    - Lens
    - Prism
  - Outer cover (*) (front, center, back)

Note 1. The product tree shows the composition of parts and components for current compact cameras. Units are large divisions of components derived from the order of process steps according to which assembly proceeds first. They also represent functional classifications. Those given in the classification as individual components are major components making up each of the units.

Note 2. The * mark in parenthesis shows that major technological innovations have occurred in the product in the past 20 years. The * mark shows that the material for the component has changed from metal to plastic. The ** mark shows that electronic components are now used. The *** mark shows that computer-aided design of lenses and their automated manufacturing are now employed. The **** mark shows that automation has been introduced in the machining of metal parts.

Figure 12. Product Tree for Compact Cameras (parts system diagram)

The following shows outlines of the conventional process steps for camera making and their changes.



Note 1. The bold line arrows show the flow of the process steps.
Note 2. Rectangles marked by wavy lines show major technological innovations that have occurred from 20 to 30 years ago to the present, and the arrows at the heads of the large broken lines show the directions of what technological changes have occurred in the process.
Note 3. The branch lines on the right sides of each of the process steps show the kinds of work and the items headed by the · mark are the work's contents.

Figure 13. Process Innovations in Cameras

Figure 14-1. Changes in Manufacturing Technologies of Mechanical and External Components for Cameras

(1) Process steps for machining metal parts (almost all mechanical parts of cameras were made of metals 25 years ago)

Pressing, cutting, casting

↓

Grinding — Polishing, grinding, cleaning

↓

Finish work
- Filing
- Polishing
- Burnishing
- Hardening
- Barrelling
- Trimming
- Buffing
- Lapping

↓

Surface treatment
- Plating — Degreasing, cleaning, plating, washing by water
- Linining
- Coating — Descaling, cleaning, coating, polishing

(2) Plastic molding process (a majority of mechanical parts and bodies of present-day cameras are made of plastics)

Dies manufacturing

↓

Plastic molding process

Figure 14. Process Innovations in Cameras

performed by electronic circuits. In the past, manufacturing of cameras would begin with the procurement of metal parts to be machined, machining and surface treating, all operations undertaken by the camera maker itself, its subsidiaries or its satellite plants. Electronic components can be purchased from outside suppliers, and all that the camera maker needs to do is mount them on a printed circuit board, thereby enabling the manufacturer to save a lot of labor. Manufacture of such electronic components lies basically outside the scope of business for a majority of the camera manufacturers, and almost all of the camera makers are consigning manufacture of electronic components to the electronics makers in Japan. The camera makers are being called upon to develop parts that meet the technical conditions specific to cameras, such as the requirements for downsizing, signal processing using extremely weak currents, etc., and they are promoting joint development with electronics makers in earnest.

In the processing of mechanical components, the operation has greatly been automated by the introduction of NC machines and by the introduction of high-speed grinders for optical components. The performance of cameras greatly depends on lenses. In the past, designing

Figure 14-2. Changes in the Process for Polishing Lenses for Cameras

(1) The lens polishing process of about 20 years ago

The process steps in squares are conducted using separate machines.
The inspection steps are conducted by humans.

Grinding material → [Rough grinding] → Inspection → [Sand spraying] → [Polishing] → Inspection →

→ [Coring] → Inspection

(2) The latest lens polishing process

A single machine can perform all the process steps from rough grinding to polishing. The shift from the polishing to the coring step is conducted in an almost automatic and continuous operation. The inspection between the rough grinding and the sand spraying step has been eliminated. The inspection from the polishing to the coring step has been reduced to random sampling of a small number of specimens.

Grinding material → [Rough grinding → Grinding (Sand spraying) → Polishing] → Inspection (Random sampling of a small number of specimens) → [Coring] → Inspection

lenses required large amounts of labor, and their manufacture demanded the skills of expert craftsmen. However, the adoption of computers in the design work and automation in the manufacturing process have greatly raised the efficiency of manufacturing.

Promoting the assembly operation by breaking the process down into several blocks has brought automation and rationalization in each of these blocks, and this in turn has contributed to a decreased number of steps for the final-assembly process and to savings in inspections, thereby greatly elevating the overall assembly efficiency.

4.2 Relationships Between Advances in Technology and Technology Transfer

These technological advances have been progressing in parallel with the growth of the structure for international division of labor. This fact led us to wonder if technological advances might not be researched from the aspects of their effects on technology transfer in the manufacturing industry.

One of the impressions we received when studying corporations was that the yardstick by which to judge the maturity of technology (the standard in the product cycle theory was a value called "the competitive power of technology") might have changed. Under the pressure of incessant technological innovation, corporate technological strategists judging at some distance from actual R&D activities, may identify technology that should be transferred abroad as mature. Of course, if some component is judged certain to generate high value added even if manufactured using expensive Japanese labor, the product may be manufactured in Japan. However, for various reasons (spiraling Japanese wages and land prices, constraints on plant operation, trade friction, etc.), corporations are almost being forced to shift their operations abroad. On the other hand, it is difficult to accurately calculate which of the so many technologies are profitable or competitive and which are not. As a result, one can say what is technologically possible to transfer abroad. The answer will be that those technologies closely related to their research and development efforts in Japan will stay behind and the rest will be shifted abroad.

The recent pace of Japanese investments in Southeast Asian countries has been great and swift. Large-scale investment was not intended merely to seek shelter from the higher costs caused by the higher yen, but the advances reflected the Japanese firms' firm conviction that management structures covering the whole world is inevitable. Japanese enterprises are forced to shift their plants in Japan to operations for manufacturing a series

of new products generated by technological innovations. Japanese firms, on the other hand, are in a situation in which they are forced to shift abroad as much of their established technologies as possible, maintain relative superiority vis-a-vis overseas subsidiaries of their competitors in Japan in the fierce competition for the market, and stabilize the management of their overseas subsidiaries. As a result of the competition for technological innovation, a situation has emerged in which the dynamism of the technology push affects technology transfer, and here research from the perspective of what effects technological advances will have becomes important.

In the following the authors summarize the results of the studies on the effects of technological advances on overseas production and technology transfer, described in Paragraph 4.1, with an emphasis on the ease of technology transfer as seen from a technological viewpoint.

(1) The gains in the functionality of electronic parts and components like ICs have greatly changed the systems of parts that go into products. This has led to reductions in the labor needed for assembling color TVs and cameras (reduced process steps, elimination of inspections, etc.). As a result, it has become easier to start assembly operations overseas by importing ICs, etc., from Japan. The innovation has created a condition favorable for the transfer of assembly technology.

(2) In the case of ICs mentioned in (1) above, the know-how of how to design ICs, accumulated over a long period of time, is all incorporated in the products themselves, so it is difficult to transfer the production technology of high-tech electronic components like ICs.

(3) The development of engineering plastics has eliminated metallic parts from cameras and as a result, the parts manufacturing process has been simplified. The innovation has created a condition favorable for the transfer of plastic parts manufacturing technology.

(4) In connection with (3) above, engineering plastics are giving rise to a simplified composition of parts in cameras. While contributing to the ease of assembling cameras, the innovation will facilitate the trend toward overseas assembly of cameras.

(5) The innovation described in (3) demands the existence of manufacturing technology of high-precision dies. This technology requires high precision and skills, so transferring it from Japan to East Asia is considered difficult.

(6) The growth of automated assembly machines, coupled with the innovations in the electronic components that go into those assembly machines, i.e., standardization, mass production and high reliability, has contributed greatly to automated assembly of color TVs. Speaking from a technical viewpoint, the manpower savings in the assembly process are considered conducive to the transfer of assembly technology. Technological advances are considered to have large effects on the ease of technology transfer.

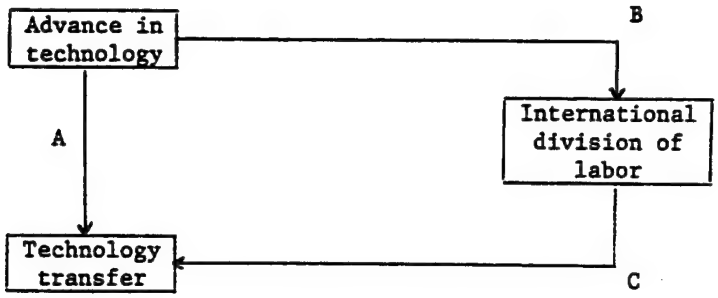
These trends may be explained from two viewpoints. As the trends in (1), (4) and (6) show, one view is that technological advances create conditions conducive to international division of labor and in this course facilitate technology transfer. According to this view, an advance in technology does not necessarily facilitate the transfer of the technology itself but it opens a way for the transfer of the peripheral technology that exploits the fruits of the technological advance, i.e., advanced parts and components. As can be seen in (2) and (3), a change in technology leads to an altered degree of ease with which the technology itself can be transferred. The case in (2) is an example in which technology transfer is inhibited, while the case in (3) is an example in which technology transfer is accelerated (Figure 15). The case in (5) is an example in which the technology of engineering plastics is accelerated, but the transfer of the technology's fundamental technology is not likely to occur.

4.2.1 Effects of Advances in Technology on "Borderless" Country-to-Country Relationships; Promotion and Limits

The authors consider what effects advances in technology have had on accelerating "borderless" corporate activity. It is assumed that the technological advances described in Paragraph 4.1 have made the following contributions to accelerated overseas production by Japanese enterprises.

The growth of components like ICs, automated parts insertion machines and parts manufacturing machines has increased the importance of technology in manufacturing. Japanese manufacturers have been waging fierce competition with one another in meeting the conditions needed for overseas production by Japanese firms, such as supply of large volumes of components at lower costs, just-in-time delivery of components, interchangeability of components with one another, and supply of manufacturing equipment. The successes of the Japanese firms' aggressive advances into Asia and the successful transformation of the assembly makers in South Korea, Taiwan and Hong Kong into electronics makers presumably were all the result of the Japanese manufacturers' meeting the conditions described above.

To be more generic, the relationship can be explained as follows: As a result of advancing high technology, the components and machines now embody the essence of technology. The distribution of technology as a commodity has increased through the acts of purchasing or selling such components and machines which are none other than the embodiments of the technology itself. Once components and machines are on hand, it is easier



(1) The "A" arrow shows a process in which an advance in technology directly promotes technology transfer.

An example is plastic molding technology. An advance in plastic molding technology has made it more suited to the technological situation in developing countries than conventional machining technology of metals, thereby making the technology more transferrable to these countries.

(2) The "B" arrow shows a process in which an advance in technology promotes technology transfer.

In an assembly-type machine industry, innovations in parts manufacturing technology facilitate the ease of transferring parts utilization technologies, which makes overseas production easier. An example is IC technology. The growth of IC technology has simplified the assembly process of electronic circuits, thereby facilitating the ease of undertaking assembly operations overseas.

(3) The "C" arrow shows a process in which increased international division of labor promotes technology transfer.

In an assembly-type machine industry, the form of international division of labor, in which assembly plants are relocated to developing countries, occurs readily. With it, the assembly technology is transferred to developing countries.

(4) The combination of "B" and "C" arrows shows the process in which an advance in technology indirectly promotes technology transfer. In this case, the technology in which there has been an innovation and the technology that is transferred may not be the same. To make it easier to understand, production technology may be broken down as follows:

Parts manufacturing technology that has achieved a technological innovation (IC, for example) plus peripheral technology that exploit the parts manufactured based on the innovative technology (assembly technology of electronic circuits, for example) equal the whole technology

■ + □ = ■

In the case of international division of labor, parts manufacturing is undertaken in advanced countries using ■, and developing countries undertake manufacturing using □. The technology that is transferred to the developing countries is not the technology that has achieved an innovation but the peripheral technology.

Figure 15. How Advances in Technology Promote International Division of Labor and Technology Transfer

for anyone to start manufacturing high-technology products using them. Such a change in the nature of technology worked favorably to not only large-scale increases in the number of Japanese firms advancing abroad but also the increased production by local-capital enterprises in Asian NIES.

Attention must be paid to the fact that in some cases, advances in the manufacturing technology of components create a condition in which the assemblers' industry based on those components finds it easier to shift their operations overseas. With the condition that sophisticated, high-reliability and standardized components are abundantly available at low cost, it is easier for anyone to assemble products incorporating those components. With supplies of components guaranteed, the jobs of assembling those components are facilitated greatly, regardless of the location of the workshop. In such a case, the technology that is transferred is not the developed technology itself but the resulting technology of how to assemble components into products.

Conversely, this fact is challenging East Asian countries with problems of how to promote industrialization in their own countries. A structural problem that machinery industries in East Asian countries face has been that although they have been receiving assembly technology, they have been receiving little parts manufacturing technology. Competition in the manufacture of electronics—the key commodities to all kinds of industrial technology—has especially been fierce, and the price, function and reliability requirements demanded of electronic components are extremely stringent. This leaves the users no other choice but to rely on established Japanese parts makers, and it is very difficult for neophytes to succeed in the electronic components market. Unless the would-be manufacturer of electronic components is technologically on a par with or superior to his Japanese counterparts, no user will dare use that firm's products because of the issue of guaranteeing quality. If his firm's products are not adopted by the user, none of the essential technological information would be forthcoming to him, which would make it impossible for his firm to catch up with technological innovations, a catch-22 situation. For these reasons, it is very difficult for firms in other Asian countries to domestically produce components. Parts manufacturers in these countries are definitely growing little by little, but their products have yet to reach high levels of technological sophistication so as to make Japanese sets makers decide to use them.

4.2.2 Degrees of Ease of Technology Transfer

Suppose a company armed with many kinds of technology is going to invest abroad and it is as yet undecided as to which of those technologies it is going to transfer to its new local operation. The decision is not made simply based on technological consideration alone but is made after taking into account various factors, such as the local labor cost, market, political issues, the availability of division of labor and cooperation with the home plant back in the country. However, the fact that the technology transfer is possible or easy from a technological viewpoint has decisive importance. From our interviews with enterprises, we tried to learn what kind of technologies lend themselves to technology transfer, and then went on to consider what relationships exist between changes in the technologies themselves and the ease with which those technologies can be transferred.

Assuming a case in which a Japanese firm advanced into East Asia, built a plant and put it into operation, we interviewed several Japanese firms. The opinion cited most often was that transcription of technology into a manual and training and education of employees are most important. From this, we will discuss the nature of technology from the angle of how best to convey technology accurately and promptly in overseas production.

(1) The Ease of Transmitting Technology—Transcription Into a Manual

When trying to transfer Japan's production technology to East Asia and put it to practical use there, the key to its success is the training and education of the employees at the local plant. The local workers must be trained and educated in a short period of time, but there are many problems, such as the gap in technological standards, language problems, and different labor practices. The practice widely adopted by many Japanese firms is to send 20 to 30 local middle-level engineers and workshop chiefs to Japan for study and on-the-job training. If these trainees are to be thoroughly drilled in the way work is conducted in Japanese plants, the contents of work must be spelled out in manuals and the trainees must go through the actual work experience through on-the-job training. Presenting the contents of work in the form of manuals and implementing a short-term employee training and education course are the key.

The transfer of technologies embodied in machinery and equipment, on the other hand, is a physical problem, so their transfer seems to pose little problem as long as the local enterprise has the capital to purchase that machinery and equipment.

(2) Character of Technologies That Tend To Be Transferred Accompanying Direct Investment

In general, the technologies that pose the greatest difficulty when transcribing them into manuals are also the ones that have the least prospect of being transferred abroad. The hard-to-transcribe technologies are considered to be those listed in 1) through 4) below, and they seem to share the following attributes: The technology's contents are fluid or are hard to recognize as something concrete; the technology has yet to be defined and standardized, and its transmission takes much labor.

1) Technologies that demand close collaboration with the design and development division;

2) Technologies that require machinery whose operation and maintenance demand much skill;

3) Technologies that are dependent on individual experience and technique and thus cannot be represented as numbers;

4) Technologies that require huge technological systems, such as aircraft, nuclear reactor and automobile technologies.

As for 1) above, recent electronic components, for example, undergo frequent model changes, so their manufacturing demands close collaboration with the research and development field. This is especially so regarding products in which the taste of the consumer is reflected, such as cameras, because the competition among manufacturers is fierce. The ease of transcribing technology into manuals is determined by the ease with which the machinery and equipment can be operated, the frequency with which specifications are altered, the degree of the high precision of the product, etc. The frequent product model changes naturally demands that components come in a variety of forms and that their designs be changed frequently.

Under such a situation, a close collaborative relationship must be maintained between the research and development division and the manufacturing floor, and technology cannot be transferred too far away geographically from the field of research and development. Since Japanese firms maintain almost all of their research and development facilities in Japan, products whose manufacture requires the type of technologies in 1) are produced in Japan.

4.3 A Framework of Relationships Between Advances in Technology and Technology Transfer

Whether or not technological innovations in the advanced countries will make it harder for developing countries to catch up with those advanced countries (in other words, whether technology transfer will be facilitated or become harder) is a matter of great concern in discussing the problem of technology development in the developing countries. Using the assumptions on the ease of technology transfer described above, we have prepared on a trial basis a framework for analyzing the relationship between an advance in technology and technology transfer.

The processes of technology transfer described above are cases involving technology transfer from firms in the advanced countries to their subsidiaries in the developing countries. In order to analyze the overall shape of technology transfer from advanced countries to developing countries, in our study technology transfers from companies in the advanced countries to local-capital enterprises in the developing countries are also included. Therefore, the difficulty of inter-corporation technology transfer is taken into consideration.

As described in Paragraph 1.2.4, a company's technology is considered an agglomeration of knowledge and know-how accumulated within the corporation over many years. Therefore, transferring a company's technology to some other company is much more difficult than transferring the technology from one division to another. In the case of intra-corporation technology transfer, the parent company transferring its technology to its subsidiary in a developing country will make an all-out effort, in both personnel and materials, to elevate the subsidiary's technological levels, so the gap in technological standards between the advanced country and the developing country will not manifest itself so glaringly. However, in the case of inter-corporation technology transfer, the technological gap between the two parties involved is a significant factor. Countries suffering from a shortage of capital will face much difficulty in trying to introduce machinery and equipment and for the country's companies, engineer training will be a tough job. Therefore, consideration must be paid to the recipient developing country's financial state and the technical standards of its engineers. As the yardsticks reflecting the recipient's technological standards, we used differences in the media through which technology is transferred into the country. Broadly speaking, a distinction is made between two forms of technology transfer, that is, whether the technology transfer took place accompanying the machinery and equipment, or whether it occurred as a result of personnel exchange.

Analyses were carried out from two perspectives of the technology transfer media and how easily technology can be propagated as represented by transcription into a manual. The former analyzes whether or not the recipient country has the infrastructure to absorb the technology transfer. When transferring technology, whether or not the recipient country has an ample foundation to digest the technology is a fundamental condition. The latter considers the ease of transmission of technology from the viewpoint of whether or not it can be translated into a manual with ease and be reproducible.

A plane consisting of two axes is given, and evaluations of the nature of the technology targeted for transfer are plotted. This way, what effect an advance in technology has on technology transfer, that is, how the "point" moves on the plane, can be inferred. This offers a way to learn the effects advances in technology have on technology transfer between North and South. This technique is used in considering the transferability of production technologies of cameras and color TVs.

Among advances in manufacturing technology are (1) automated production, mass production, and cost reductions, (2) increased reliability and downsizing of products, (3) increased variety and multi-functionality of products, and (4) simplified structures of products. Consideration is given to each case.

(1) Automated assembly in the manufacture of TVs is considered to move the "point" downward in the Y axis direction and left in the X axis direction (Figure 16, arrow 1).

(2) The sophistication in the manufacturing technology of chips is considered to move the "point" downward in the Y axis direction (Figure 16, arrow 2).

(3) The growth of IC manufacturing technology is considered to move the "point" downward in the Y axis direction and right in the X axis direction (Figure 16, arrow 3).

(4) The simplified assembly in the manufacture of watches, brought about by the adoption of quartz technology, is considered to move the "point" left in the X axis direction (Figure 16, arrow 4).

When the three regions of Japan, Asia NIES and ASEAN with different technical infrastructures are considered, each is considered to have a niche in the technological plane where conceptually it is strongest. That is, the technical areas where the ASEAN and Asian NIES are strongest are found in the middle and bottom sections, the areas where the requirements for engineers and capital are not so high, of the left side of the technological plane, the area where technology can be easily transcribed into manuals. To the right lies the area where NIES have an edge. The far right side and the top area are where Japan is strongest.

ASEAN and Asian NIES are suffering from a shortage of engineers, and ASEAN countries also lack capital. In the cases involving technology transfer by Japanese firms, the restraining conditions are considered stringent, so the range of technologies that are transferable to Asian NIES and ASEAN will be narrowed. Cases of technology transfer to Asian NIES and ASEAN involving intra-corporation technology transfer, on the other hand, are considered to have large room for expansion.

Figure 16 gives schematic drawings based on data obtained during the survey. They will enable the reader to see that an advance in technology will not necessarily work to the detriment of the developing countries.

5. Conclusion

5.1 Conclusion

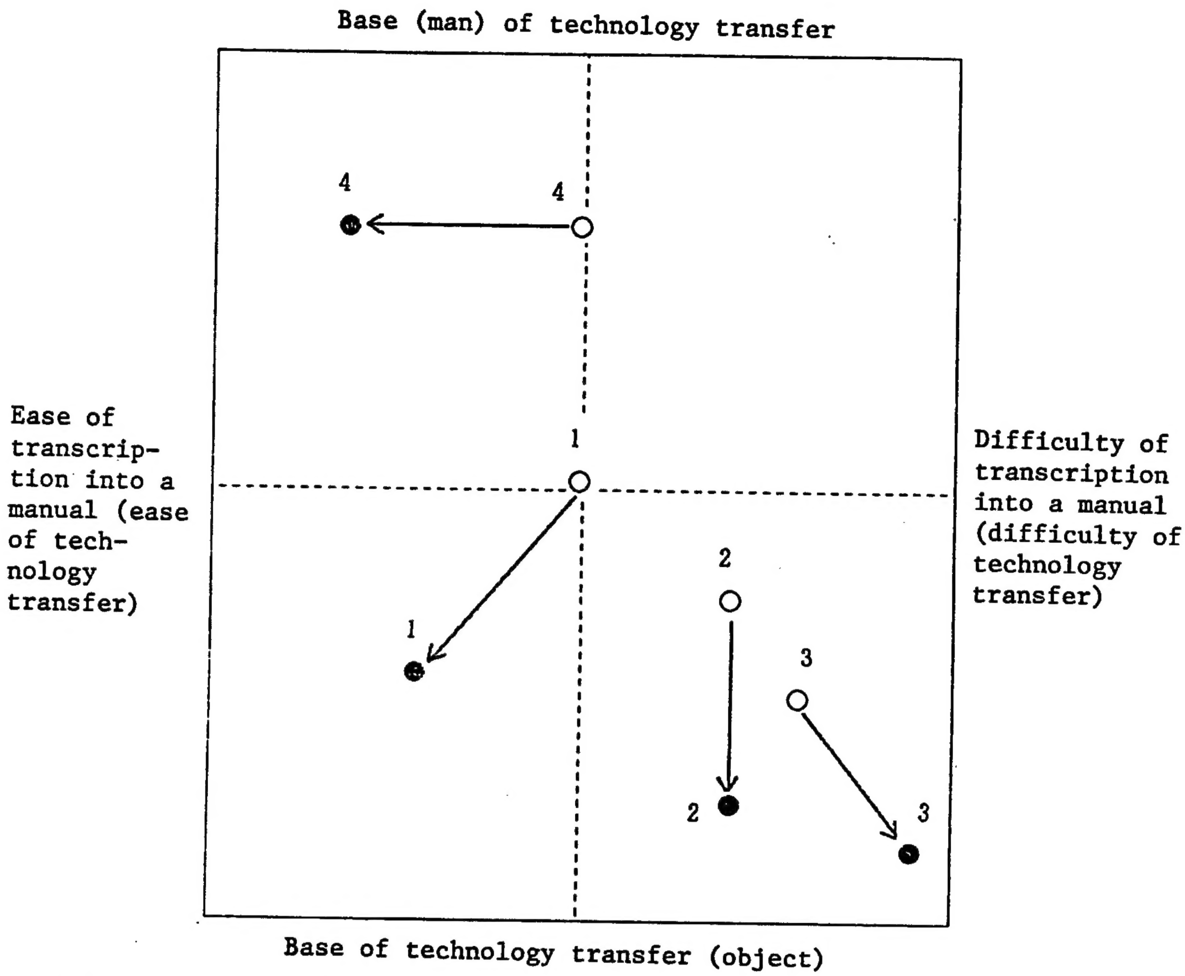
The achievements of this survey and research can be summarized as follows.

First, we devised a method to measure the transfer of technology accompanying the start of production abroad. That is, in order to more accurately show the degree of technology transfer in this day when activities of corporations have become more international, we noted the level of procurement of components in overseas production. By investigating what major components came from what firms in what countries, we estimated the progress of technology transfer.

Second, using the above measuring method, we conducted case studies of color TVs and cameras and succeeded in analyzing the actual state of transfer of parts manufacturing technology accompanying the start-up of overseas production, a fact not recognized widely. In the case of color TVs, as a whole, about half the components were purchased from local subsidiaries or affiliates of Japanese firms, which shows that technology transfer from Japan to East Asia has progressed as a result of direct investments by Japanese firms. By components, technology transfer is highly advanced in cabinets and general electronic components but transfer of technology to manufacture semiconductors such as ICs and transistors is not progressing (Figures 6 and 7). The progress of technology transfer in camera manufacturing is as a whole slower than that for color TVs. By components, technology transfer is advancing in plastic parts such as gears but in electronic components such as ICs is slow (Figures 8 and 9). Furthermore, when the technology transfers accompanying overseas production are classified by their forms of transfer, that is, intra-corporation transfer and inter-corporation transfer, technology transfers in both color TVs and cameras were mostly done through intra-corporation transfers. Overseas production has had little effect in accelerating inter-corporation technology transfer. Although the number of samples used in our survey was small, the results have proved that our survey method was effective.

Third, from this analysis, it was learned that there exists a structural problem in the development of technology in East Asia. In the aforementioned industries, there exist networks of parts makers who are subsidiaries or affiliates of Japanese firms, and Japanese enterprises establishing operations in the area purchase major components from these networks. This enables those Japanese enterprises to lower the costs of their products while maintaining the high quality of the components that go into those products, and at the same time it enables them to clear the local content law. These networks are an inevitable condition if transfer of production activity abroad by Japanese firms and the accompanying technology transfer are to progress smoothly. Conversely, from the viewpoint of developing countries, this form of division of labor means that although transfer of assembly technology is forthcoming, transfer of production technologies of major components must await capital investments by foreign companies, thereby slowing the progress of domestic production and putting a limit on the growth of technology as a whole.

Fourth, it must be pointed out that with the competition for technological innovation as a background, advances in technology are having an effect on technology transfer. The characteristics of technological advances in color TVs and cameras have been examined from the perspectives of the products tree and process innovation. The results revealed that advances in technology and technology transfers accompanying the start-ups of overseas



Note 1. The round marks show the planar positions of the technology's nature in the past (20 years ago) and at present. The arrow mark shows the tendencies of change.

o → ●
Past Present

Note 2. The numbers show innovations in the following technologies.

1 Advances in the assembly technology of small color TVs (automation, mass production)
2 Advances in the manufacturing technology of chip-type electronic components (miniaturization, higher reliability)
3 Advances in the manufacturing technology of ICs (diversification, multifunctionality)
4 Advances in the assembly technology of watches

Figure 16. Analysis of Relationships Between Advances in Technology and Directions of Technology Transfer

production occurred hand in hand and that some types of advances in technology had the effect of accelerating technology transfer.

Regarding the latter, a tendency is observed in which technological progress altered the optimal technical condition for production and that technology tended to be transferred to those countries having such a condition. In the case of cameras, for example, the adoption of plastic forming technology has facilitated the processing of components and the adoption of ICs has simplified the assembly process. These technical innovations probably have been advantageous to the transfer of camera manufacturing technology to Taiwan and Hong Kong which lack the foundation for high-precision metallurgy.

The use of high technology by East Asian countries has also been facilitated by the fact that the present-day components, such as microelectronics, and machinery and equipment are nothing but the embodiments of high technology and that such high-tech products have come to be widely used. In this case, high-tech itself is a black box, and this makes the content of the technology more difficult to take out of Japan (Figures 11 through 14). These facts are interpolated into the idea that we have proposed as a framework for analyzing the effect of technological progress on technology transfer.

From the administrative point of view, the implications derived from this analysis are the following:

First, the development of a method to measure technology transfer has deepened the understanding of the current state of technology transfer which is the starting point for discussing international technology transfer between North and South.

Second, regarding technology transfer from Japan to East Asia accompanying the shift of production activity from Japan to the area, it is apparent that intra-corporation technology transfer progresses but inter-corporation transfer of parts manufacturing technology hardly progresses. This poses a structural problem for the East Asian countries in fostering their own technology.

Third, it has been proven that as technology advances, advances in technology promote technology transfer to some degree. This view suggests where the diffusion of high technology in the South will head. This technological directionality will be helpful in clarifying the course of technological growth for the South, that is, to determine what technologies the South will obtain by what means.

In the past studies on international technology transfer, not much was done from the angle of how overseas investment will cause what portions of an entire components technology system needed to manufacture a product to be transferred abroad. We conducted our current survey and research from the aforementioned angle in view of the fact that advances in the parts manufacturing technology have turned the components themselves into embodiments of high-tech. This approach has enabled us to present a clue to what has contributed to the rapid industrialization that East Asian countries have achieved and to provide suggestions as to what are the structural problems in these countries.

5.2 Tasks for the Growth of Technology in East Asia

(1) Promoting Informal Technology Transfer

From the viewpoints of East Asian countries, the fact that the amounts of technology that can be transferred as a result of the start-ups of overseas production by Japanese firms are still limited may convince those countries that there is good reason for them to ask Japan to transfer its technology more liberally. The circumstances are a reflection of differences in the technological structures between Japan and East Asian countries and trying to solve these problems politically may not be desirable. It is hoped that efforts will be made to create conditions conducive to technology transfer. There should be discussion at least on under what state and structure technology transfer is being promoted at present, based on objective analysis.

When the problem is considered with the existing technological structure between Japan and East Asian countries as a precondition, the following conclusions may be derived from our current survey and research. Technology transfer from Japan to local-capital enterprises provides an important technology resource for those local-capital firms receiving the transfer. However, since such transfers are conducted on a commercial basis, it is not always the case that the requested technology is readily transferred, partly because of the differences in the technological levels between Japan and these countries. Our case studies have also shown that cases of technology transfer in which technology goes outside the networks of the advanced countries are very few.

In order to raise the levels of technology in the developing countries, it will be necessary to encourage leaks of technology from the technology networks of Japanese enterprises or those of other advanced countries to the local enterprises. How the receiving end of the "technology leakage" has been able to effectively use the leak has been the decisive factor that has spawned the difference in the performance from one country to another. If the leakage is to become a stream, it is absolutely necessary for the receiving end to train and educate as many talented people capable of absorbing advanced technology as possible. To such end, the Japanese will be extending their cooperation in the field of training and education of talented personnel. Japan has until now been cooperating in the local countries' efforts to train and educate talented personnel, and it is being asked to continuously extend assistance in a variety of fields on the part of the private sector as well as the government.

Furthermore, non-typical technology transfer like the spin-out of talented personnel from firms in advanced countries will become important (Figure 3). In Thailand, the dearth of engineers is leading them to move from one job to another frequently (job-hopping). However, the skills of the job-hoppers are not necessarily put to good use at their new jobs, and the result is that the accumulation of indigenous technology is slow. The governments in the developing countries may be advised to

institute an expert management system of their own engineers so that there will be an infrastructure conducive to those enterprises needed to promote industry in their countries and to research organizations, as well as to provide some incentives.

(2) New Direction—Enhanced Research and Development Capability

Japanese enterprises have rapidly been expanding their international activities, and with it, the international division of technology is dynamically changing. Forecasting the future direction of technology is also a task that must be undertaken.

The direction is toward the localization of advanced technology development functions by Japanese enterprises. It will be necessary for Japanese firms to shift their manufacturing operations of high-tech products and their research and development capabilities to Asian countries. As the earnings of the people in East Asia rise, the overseas plants of the Japanese enterprises will surely be hard pressed before long if they confine their activities to the manufacture of only end-use products.

Overseas production by firms started with screw-driver plants specializing in assembly. Next came the procurement of components from the local manufacturers. The development at present is toward local manufacturing of products requiring higher technology. The Singapore subsidiary of a leading Japanese maker of electronics has started manufacturing pickups, the key component in compact disc players. Although a trend with a small group of high-tech companies, recently they have begun to diversify their research and development capabilities abroad and to manufacture components locally. For example, a Japanese camera maker has started product development in Hong Kong. According to the company, some aspects of the developmental work are still difficult without the assistance of Japanese engineers but the local R&D capability has steadily been rising. Development of computer software and the design work of ICs are now undertaken in Asian countries. The progress of technological innovations is motivating change in the business mode of overseas production.

In June of last year, a staff member of a local subsidiary of a leading Japanese company told me that the local labor is superb. Corporations will find great advantages in the exploitation of Asian talent. The corporate structure of Japanese firms must change so that the abilities of the excellent labor force of East Asia will be displayed to the fullest in the local subsidiaries of those Japanese firms.

The structures of technologies and the recent activities of corporations, described above, will largely determine the prospects of technological growth in East Asian countries and developing countries in general. If these countries are to advance still further technologically, it is important for them to master not only the techniques of operating and maintaining manufacturing equipment but also the principles of designing and manufacturing products, and details of the know-how pertaining to their manufacturing. In this context, it is important for the developing countries to make sure that the technology transfers that have materialized as a result of investments in their countries by the advanced countries will take root and be employed widely.

If East Asian countries are to see their technology grow in the future, it will not be enough for them to merely import advanced technology. They are being called upon to develop their own R&D foundation that will enable them to improve on the introduced technology, so that they will be able to continuously exploit the technology through the course of technological innovations. Fully aware of this, East Asian countries on the road to industrialization have been implementing measures to promote science and technology, such as establishing research institutes. The aforementioned activities of the Japanese firms are in agreement with the needs of East Asian countries.

Once East Asian countries have succeeded in elevating their R&D capabilities partly by exploiting the increasing trend among the enterprises in the advanced countries to shift their bases of R&D abroad, this, together with the basic technologies that have already arrived, will accelerate the sophistication of technology in East Asia in a three-dimensional way.

Conclusion

In our current survey and research, we have analyzed how technology transfer in the color TV and camera industries has progressed, and studies must also be made separately on how technology transfer in agriculture and energy has progressed and what are the routes of the technology transfers. In order to grasp the whole picture of technology transfer, measurements must be taken by appropriate methods in many fields and observations will also have to be done on the dynamism of the progress of technology. We hope this survey and research will provide a step in that direction.

Headed by South Korea, Taiwan and Singapore, East Asian countries are pursuing the road to high technology. The approach to drafting a science and technology cooperation policy in Japan must begin with studying from multifarious angles the various aspects of science and technology in East Asian countries.

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